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HUMAN PERFORMANCE CENTER

DEPARTMENT OF PSYCHOLOGY

The University of Michigan, Ann Arbor

A Psychophysical Approach to Form Perception: Incompatibility as an Explanation of Integrality

PATRICIA WENJIE CHENG

Technical Report No. 65
July, 1980

THE HUMAN PERFORMANCE CENTER

DEPARTMENT OF PSYCHOLOGY

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Integrality refers to an apparent difference in the perceived distinctiveness of visual dimensions. Some combinations of physically independent dimensions appear to fuse into a single perceptual attribute, while other combinations appear to leave the physically independent dimensions perceptually distinct. This apparent difference in the perceived distinctiveness of visual dimensions have previously been explained by the postulation of two types of → over

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internal representations. One type is assumed to have a similarity (integral) structure, while the other type is assumed to have a dimensional (separable) structure. To define these two types of structures, a set of converging operations has been proposed, including a pattern of performance in speeded sorting (Garner, 1974). However, the pattern has not always been found to fall neatly into two categories. In particular, degrees of integrality and asymmetric integrality have been observed.

This report attempts to show that two crucial operations defining integrality--interference and condensation time in speeded sorting-- as well as degrees of integrality and asymmetric integrality can result from a single type of structure, the dimensional type. It attempts to show that these patterns of performance can be explained by the compatibility of physical dimensions with psychological (i.e., separable) dimensions.

Experiment I showed that a psychophysically compatible dimension did not produce interference, whereas psychophysically incompatible dimensions did, as predicted by the psychophysical compatibility theory. In this experiment, compatibility was defined by the compellingness of dimensions. Experiment II showed that degrees of compatibility (as defined by the orientations of sets of stimuli in a multidimensional scaling representation of similarity judgments) could explain the occurrence of interference, the inverse relationship between interference and condensation time, and degrees of integrality (as indicated by gradations of the pattern of interference and condensation time). Experiment III attempted to show that in accordance with the compatibility theory, the compatibility of single dimensions can generally be evaluated independently of the compatibility of concomitantly varied dimensions. This independence implies that if one manipulated dimension is psychophysically compatible while another is not, asymmetric integrality will result. In this experiment, the compatibility of a dimension was evaluated in the context of two irrelevant dimensions, as well as with different values along the same irrelevant dimension. Compatibility was defined phenomenologically as well as by the amount of interference. Results showed that the compatibility of a dimension was not consistently affected by variation along other dimensions.

In addition to the above, this report explored the property of rectangularity--a potential systematic definition of psychophysically compatible dimensions. Rectangularity refers to the shape of the multidimensional configurations derived from judgments of the overall similarity of pairs of stimuli. If stimuli of equal difference along physical dimensions are judged equally dissimilar regardless of values along other physical dimensions, then rectangularity will obtain. It was concluded that rectangularity is not a sufficient definition of compatible dimensions, and it was tentatively concluded that it is not a necessary definition of compatible dimensions.

The results obtained at least imply that Garner's definition of integrality is inadequate. In place of his definition, two new operations were proposed: the effect of dimensional within-class variability with appropriate controls, and the effect of the orientation of a fixed configuration. The findings furthermore imply that a single type of internal representation (the dimensional type) may account for integrality and separability.

THE UNIVERSITY OF MICHIGAN

COLLEGE OF LITERATURE, SCIENCE AND THE ARTS

DEPARTMENT OF PSYCHOLOGY

A PSYCHOPHYSICAL APPROACH TO FORM PERCEPTION: INCOMPATIBILITY AS AN EXPLANATION OF INTEGRALITY

Patricia Wenjie Cheng

HUMAN PERFORMANCE CENTER TECHNICAL REPORT NUMBER 65

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CHAPTER I

INTRODUCTION

In any domain of science, if a variable manipulated is not the pertinent variable, or if a variable observed is not the pertinent variable, lawful patterns will not emerge. My aim in this study is to examine in this light dependent and independent variables in the domain of the visual phenomenon of integrality.

I will briefly summarize the state of the art with regard to integrality before describing a new approach at some length, with the aim of putting it in historical context.

1.1 Integrality and Separability

Some stimulus dimensions, such as shape and color, are phenomenologically compellingly distinct, while others, such as brightness and saturation, are in combination perceived more as a unitary entity:This apparent difference in the perceived distinctiveness of visual dimensions is the starting point of a growing literature on the internal representation of visual information. Intuitively, integrality refers to the phenomenon of dimensions appearing to fuse together into a single integral attribute. Its complementary concept--separability--refers to the phenomenon of dimensions appearing compellingly distinct.

From this phenomenological distinction, the concept of integrality has evolved to include various operational definitions. As is often the case in tracing a notion's conception, it is somewhat arbitrary to pin-point in the scientific community an absolute beginning. With this qualification in mind, it may be said that Torgerson (1958) first formed a synthesis from various embryonic strands and called attention to the phenomenon. He characterized one type of visual information as "multidimensional" (integral), and another type as "dimensional" (separable). He further suggested that they were respectively best modeled by a Euclidean space and a city block space. Attneave (1962) and Shepard (1964) stated similar ideas. The phenomenon was later related to facilitation and interference, or the lack of them, in speeded sorting (Garner and Felfoldy, 1970; Lockhead, 1966). This sequence of theorizing culminated in Garner's (1974) Processing of Information and Structure.

1.1.1 Garner's Theory

The primary thrust of Garner's theory lies in the postulation of two types of internal representations or structures: one characterized by similarity relations in a Euclidean metric, where the rotation of the axes is inconsequential; the other characterized by dimensional relations in a city block metric, where there is a fixed set of axes.

On the basis of these two metric models, Garner proposed a set of converging operations for distinguishing between integral and separable dimensions. These operations included measuring a person's ability to selectively attend to one of two orthogonally varied dimensions, gain in sorting speed with correlated dimensions, and reaction time in condensation (following Posner's , 1964, terminology). These operations can best be explained by reference to Figure 1. This figure is a schematic diagram of a set of four stimuli generated by an orthogonal combination of values on two dimensions. To measure the ability to selectively attend to, say, dimension X, the time to classify stimuli A and C against stimuli B and D (this task will from here on be referred to as orthogonal sorting) is compared to the average amount of time to discriminate C from D and to discriminate A from B (this task will from here on be referred to as unidimensional sorting). If a person is able to selectively attend to dimension X, then the orthogonal sorting task should not take any longer than the unidimensional sorting task . Presumably,information on dimension Y can be ignored, such that A and C are psychologically the same stimulus (they are of the same value on dimension X), and B and D are likewise psychologically the same stimulus. In such a case, sorting four stimuli should take no longer than sorting two. This is assumed to be the case with separable dimensions, where dimensional values are assumed to be important. In contrast, with integral stimuli, similarity relations are assumed to be important. Since there is dissimilarity (as defined by the Euclidean distance between stimuli) between A and C, and likewise between B and D, each of the

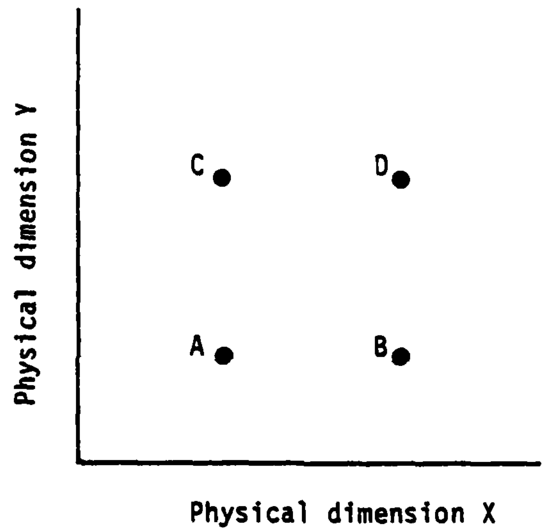


Figure 1. A schematic diagram of a set of four stimuli generated by an orthogonal combination of values on two physical dimensions. Dots denote stimuli.

response classes has two distinct stimuli, as compared to only one for separable dimensions. This within-class variability lengthens classification time; classifying four distinct stimuli takes longer than classifying two. The mean increase in classification time from the unidimensional to the orthogonal sorting task is referred to as interference. For integral stimuli, the irrelevant dimension (dimension Y in this example) interferes with sorting on the basis of the relevant dimension (dimension X in this example). It was hypothesized that the more dissimilar the stimuli are within a response class, the greater the interference; and the more dissimilar the stimuli are between the response classes, the less the interference (Garner, 1974; Lockhead and King, 1977). The orthogonal task has sometimes been called filtering (Posner, 1964) because of the requirement that the person filter out one dimension while attending to the other.

A second operation measures the gain in speed in sorting two stimuli that have correlated values on the two dimensions--for instance, A versus D--as compared to the mean sorting time of the two unidimensional tasks. For separable stimuli, when the faster of the unidimensional tasks is taken as the baseline for comparison, there should be no gain in speed. This is because the distances projected onto the dimensions between the stimulus pair in a correlated task are the same as the distances between stimulus pairs in the unidimensional tasks; and dimensional distances are assumed to predict performance. For integral stimuli, however, Euclidean rather than dimensional distances are assumedto predict performance. Since there is an increase in Euclidean distance for a correlated pair of stimuli,as compared to a pair of stimuli in a unidimensional

task, sorting should be faster with the correlated pair.

A third operation is condensation time. This task has been called condensation (Posner, 1964) because it requires that the subject condense information from two or more dimensions defined by the experimenter. The simplest condensation task, the one used in all experiments mentioned in this dissertation, requires that the subject classify the diagonals of an orthogonal set of stimuli into two categories (i.e., A and D versus B and C). It has been observed that this task took longer for separable than for integral stimuli (Garner, 1974). This was explained by the assumption that in order to perform this task, the subject had to attend to two separate dimensions for separable stimuli, but had to attend to only one single attribute for integral stimuli.

There were additional converging operations such as free sorting. However, speeded sorting, in particular speeded sorting of orthogonally varied dimensions, has become the core of the set (Garner, 1978; Pomerantz and Sager, 1975). Orthogonal sorting has been regarded as the most diagnostic, and is often used alone to indicate integrality (Garner, 1978; Pomerantz and Sager, 1975; Smith and Kemler, 1978).

In sum, Garner proposed two kinds of perceptual representations with consequent differences in process and hence in performance.

1.1.2 A Problem with Garner's Definition

Problems with Garner's definition have been mentioned elsewhere (Pachella, Somers and Hardzinski, 1979; Somers, 1978). A major one is that the converging operations have frequently been found not to converge. For example, Garner and Felfoldy (1970) found that

dimensions that should be compellingly integral yielded the expected facilitation of reaction time with correlated dimensions, but surprisingly little interference when selective attention was required. This led Garner (1974) to suggest that integrality might be a continuum, that there are degrees of integrality. In a similar vein, Smith and Kemler (1978) proposed a "continuum of dimensional primacy". The concept of degrees of integrality, when we consider it, is quite incongruous with the concept of two distinct types of psychological structures. The idea of a continuum between two distinct structures is highly unnatural, if not self-contradictory. Pomerantz and Sager (1975), after concluding that two dimensions were integral from the presence of interference on both dimensions, went on to call the dimensions "asymmetrically integral", since the amount of interference between the two dimensions was asymmetrical. Kemler and Smith (1979) found that subjects had a tendency to use dimensional rather than similarity relations in a concept learning task, even for the ostensibly integral dimensions of brightness and saturation. Such intermediate combinations of results have led to a burgeoning taxonomy of types of integrality (Garner, 1974; Garner, 1978; Garner and Felfoldy, 1970; Kemler and Smith, 1979; Pomerantz and Garner, 1973; Pomerantz and Sager, 1975; Smith and Kemler, 1978). This taxonomy serves little purpose other than to simply label the different combinations of results.

1.2 A Psychophysical Approach

In view of the growing chaos surrounding the concept of integrality, an alternative approach is taken. This approach is

psychophysical, in the sense that it attempts to find simple, functional relationships between the physical and the psychological variables.

Traditionally, psychophysics related single physical dimensions of isolated simple stimuli to psychological dimensions. The dimensions--physical and psychological--are assumed to correspond: only units are different. Thus, for instance, brightness is some function of light intensity. In the case of classical psychophysics, within a certain range, the psychological response is a direct function of the proximal stimulus, and the proximal stimulus is a direct function of the physical stimulus.

When objects in the real world are considered, however, a perplexing problem appears: percepts no longer seem to be a function of the proximal stimulus. Children and adults remain their respective sizes as they approach and recede. Our percepts correlate with distal stimuli rather than with proximal stimuli. Yet, proximal stimulation holds <u>all</u> the information we have of the outside world. Psychophysics seems to have broken down at this level, at least according to the traditional approach to this problem.

But psychophysics need not break down. The lack of correlation between proximal stimulation and perception may well be due to the arbitrary physical dimensions with which we have chosen to describe the proximal stimulus. Higher order variables in the proximal stimulus may exist, of which our percepts are functions (Gibson, 1960; 1966). These higher order variables in the proximal stimulus are in turn functions of physical variables. A psychophysics of perception

might exist, if only we could find the correct (not necessarily higher order) variables.

It may seem then that visual illusions would have to be partitioned out of the domain of this approach. Gibson (1966) in fact did so. Illusions, by definition, are not functions of the physical stimulus. However, this need not be the case. Just as traditional variables specifying proximal stimulation may not be the pertinent variables, traditional variables specifying physical stimulation may also not be the pertinent variables. The same argument applies. Indeed, perceptual constancies were visual illusions according to the Introspectionists.

Gregory's (1966) explanation of the Mueller-Lyer illusion may be regarded as an instance of this approach to visual illusions. According to this explanation, we perceive the three-dimensional length of the shafts of the arrows-- as in the internal and external views of the corners of buildings-- while cognitively recognizing that the shafts, if perceived as two-dimensional, are of equal length. Hence the illusion. When the arrows were indeed presented three-dimensionally, there was no illusion. It is obvious that the Ponzo railway illusion may be similarly explained. In sum, illusions might arise from a mischaracterization of the physical stimulus.

This approach can be extended to the phenomenon of integrality. The connection may be made more apparent by a restatement of the phenomenon of illusions: When a certain variable is put into the context of another variable, the first variable can no longer be attended to selectively. The combination produces an effect on the

perception of the former, perhaps by creating a new higher order variable. The phenomenon of integrality can be stated in the same way. As in the case of illusions, our failure to selectively attend to integral dimensions may be a pseudophenomenon arising from a mischaracterization of the physical stimulus: the physical stimulus may be characterized by the investigator in a way incompatible with that physical stimulus which is psychologically pertinent to the observer.

1.2.1 Psychophysical Compatibility Theory

The following is a new version of the psychophysical compatibility theory based on the one stated by Pachella, Somers, and Hardzinski (1980). An assumption underlying this theory is that regardless of what physical variables are manipulated, people always encode stimuli in psychological dimensions. These dimensions, being psychological, can by definition be selectively attended to. That is to say, they should be separable. It follows then that physical variables corresponding to psychological attributes would be seen as separable. Consider, for example, the perception of a triangle. Suppose that the compelling attributes of a triangle are its height, its shape, and its size. Changing the value of each of these would naturally be seen by the observer to change the value of only one of the psychological attributes, either height, shape, or size. Note that while a triangle may be specified by the above three dimensions, it may alternatively be specified physically in any number of ways, by the lengths of its three sides, or by the lengths of two sides and an included angle, and so on. Now, when the physical variable manipulated does not correspond to any psychological attribute, it will cause variation

in more than one psychological attribute. For instance, by changing the length of any one side of a triangle, one would simultaneously change its height, its shape and its size. Moreover, triangles with a certain length of left side, for instance, could adopt many heights, shapes and sizes depending on the lengths of the other two sides. That is, stimuli with a constant value along a psychophysically incompatible dimension, depending on the values on other dimensions, could have different values along the psychological dimensions. Thus, values along such an incompatible physical dimension, whether constant or varying, would not be perceived as independent. According to this theory, then, it is the compatibility between physical and psychological attributes which determines the degree of integrality. Physical dimensions compatible with psychological attributes will be separable, those incompatible will be integral.

According to this theory, interference in orthogonal sorting occurs because displays to be sorted into the same category, although of the same value on a physically manipulated dimension, are in fact of different values on the psychological dimensions. It is this perceived difference between stimuli of the same class which leads to interference. Since this difference lies on the same relevant psychological dimension, it is logically impossible to filter. Not only can this lack of correspondence account for sorting performance on orthogonally varied stimuli, it can similarly account for performance on correlated sorting (Pachella, Somers, and Hardzinski, 1979; Somers, 1978) and condensation (Cheng and Pachella, 1979; Pachella, Somers, and Hardzinski, 1979).

Thus, the pattern of performance proposed by Garner (1974) to

define integrality can result from a lack of correspondence between physical and psychological dimensions. This means, at the very least, that the pattern is not a sufficient definition-- it can arise from a stimulus domain with separable dimensions. If this is the problem, then, while Garner's original idea of two structures can still be retained, integrality and separability will need to be operationally thoroughly redefined. Furthermore, it may imply that one type of structure alone -- the dimensional type -- can adequately handle the data. Performance hitherto associated with integrality might always be due to incompatibility.

Jumping from the first to the second possibility theoretically requires an exhaustive demonstration that all cases of integrality are due to incompatibility. This is obviously beyond the scope of this study. Here I shall limit myself to demonstrating incompatibility for only one stimulus domain. Some of the other domains investigated will be discussed in the concluding chapter. The hypothetical psychological dimensions chosen here are size and shape. They are chosen because they are not obviously integral or separable; yet we do have some intuition as to what the dimensions might be.

The compatibility theory does not necessarily assume that dimensions are organized geometrically in a coordinate space. The theory has just been stated without this assumption. Thus, criticisms raised against geometric models with dimensional and metric assumptions (Tversky, 1977) are not relevant. In fact, the non-coordinate dimensional concept required here may be regarded as a generalization of the feature concept favored by Tversky (1977). A feature model is

a special case of a dimensional model where, say, for the purposes of a particular task, only two values -- present or absent -- along the dimension are used, although a continuum is potentially available.

However, even though the assumption of organization into a coordinate space is not essential to the logic of the theory, the nature of the set of stimuli we are presenting renders this assumption both plausible and convenient for expository purposes. The assumption will therefore be explored and used. However, the rejection of this assumption does not imply the rejection of the compatibility theory.

Both the concepts of dimensional and of similarity structures assume that we organize information into qualities. To better delineate these concepts, it may help to paraphrase them in terms of qualities and quantities. Dimensionally represented stimuli have qualities along which differences could exist and could only exist in purely quantitative amounts; stimuli represented by similarity relations, besides having qualities along which differences exist in quantitative amounts (according to distance from the origin), can also have positional differences. A geometric model is involved. Even within each quality, stimuli do not merely possess more or less of the quality. They may differ from each other by their positions in the space in a respect other than distance from the origin. For instance, a pair of stimuli with a and b amounts of an integral quality can have a certain distance between them. (See Figure 2.) Another pair of stimuli with a and b amounts of the same quality can have a different distance between them, depending on the

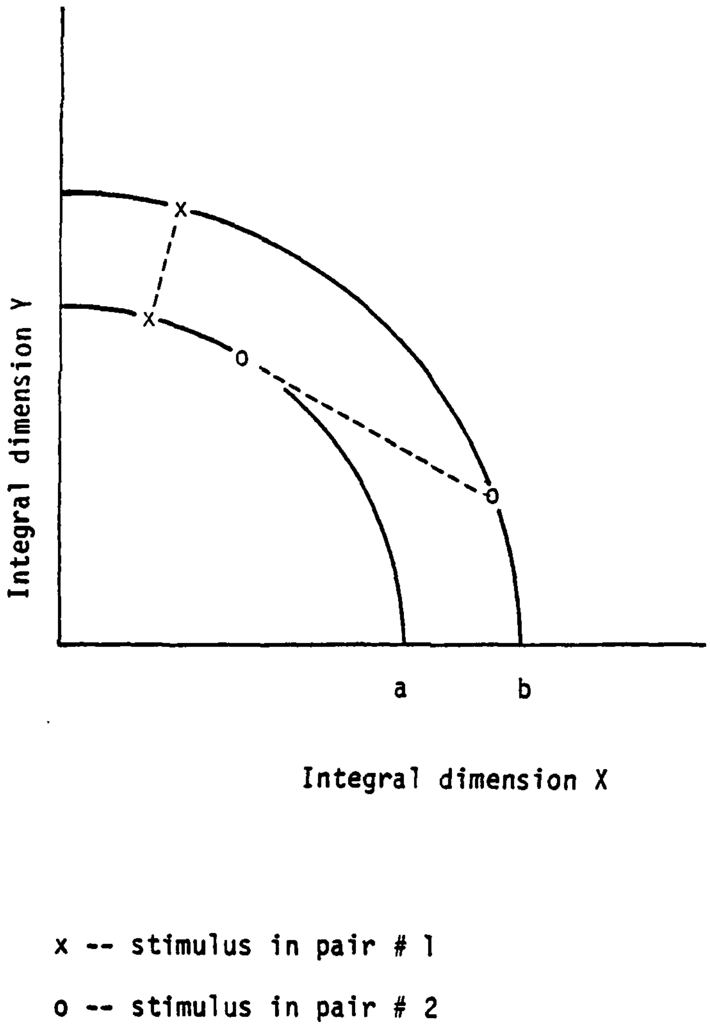


Figure 2. Pairs of stimuli encoded in integral dimensions.

relative positions of the members of the pair with respect to each other. This distance between members of a pair, which is not determined by the quantitative amounts possessed by the members--as is the case for dimensionally encoded stimuli--is nevertheless an important determinant of performance. This illustrates the inherent complexity of a similarity structure (also see Hyman & Well, 1967).

1.2.2 Previous Results

Somers (1978) attempted to validate the compatibility theory. Her goal was to construct two sets of stimuli --one by the orthogonal combination of dimensions compatible with psychological structure, the other by the orthogonal combination of dimensions incompatible with psychological structure-- and show that the incompatible set leads to a pattern of performance defined as integral (Garner, 1974); the compatible set,a pattern of performance defined as separable. To do so, an indicator of compatibility independent of performance in speeded classification tasks is needed. In other words, a separate dependent variable measuring compatibility is needed. Otherwise, the theory would be *post hoc*: whenever the pattern of performance is indicative of integrality, the dimensions are designated incompatible; whenever the pattern of performance is indicative of separability, the dimensions are designated compatible.

1.2.2.1 Rectangularity

As a separate measure of compatibility, the concept of rectangularity was introduced. It refers to the shape of multidimensional configurations derived from judgments of the overall similarity of pairs of stimuli. This measure is based on a set of assumptions. One is that psychological, or perceived, dimensions are independent, by virtue of their definition as psychological dimensions (Stevens, 1934). A second is that ratings of overall similarity are capable of reflecting this independence. The concept of rectangularity is formalized in a set of axioms of the geometric models of similarity underlying multidimensional scaling. These axioms, stated by Tversky and Krantz (1970) and Krantz and Tversky (1975), include interdimensional additivity, which states that the perception of similarity among multidimensional stimuli is an additive combination of their similarity along each of their component dimensions. Interdimensional additivity implies that equal physical differences on one dimension will be perceived as equally similar independent of the values along the other dimension.

The task involves obtaining judgments of overall similarity on all possible pairs of stimuli in a set. The set is constructed by orthogonal combinations of values on two physical dimensions. When judgments on each dimension are independent of values on the other dimension, a multidimensional scaling representation of these judgments will be rectangular (Somers, 1978). At the introduction of this concept, the theory becomes geometric.

Somers (1978) measured the degree of rectangularity of stimulus sets by the amount of interaction(I), defined as the ratio of

diagonals of a multi-dimensional scaling configuration of a set of four stimuli formed by orthogonal combinations of two dimensions. Two stimulus sets were constructed in this way, one interactive ($I \neq 1$) and the other non-interactive ($I=1$).

1.2.2.2 Evidence Cited in Support of Compatibility Theory

The three lines of evidence Somers cited in support of the compatibility theory were:

1. In the interactive stimulus groups, sorting time for positive diagonals was longer than for negative diagonals. This was consistent with the greater similarity of stimuli lying on the positive diagonals.
2. Interaction was correlated with the amount of interference. Both of the two subjects tested showed a correlation coefficient of .41. For one of them, a significant amount of interference resulted from the interactive set, but not from the non-interactive set. The non-interactive dimensions for this subject were $HR^{.8}$ and $AR^{.2}$ (H stands for height, R for length of right side, and A for area of triangle.)
3. When the relative discriminability of the two dimensions was kept constant and high, interaction had an effect on sorting time, though in a rather unpredictable manner.

These lines of evidence do not provide adequate support for the compatibility theory for the following reasons.

First, although the difference between positive and negative diagonals in sorting time is not predicted by Garner's theory, the theory could, however, be readily modified to accommodate it. Garner (1974) assumed that the similarity space representing these dimensions can be derived from the unidimensional -- perhaps regularly distorted --

mappings between single physical dimensions chosen by the experimenter and single psychological dimensions. It follows then that in correlated sorting, since the physical lengths of the two diagonals are the same, the psychological lengths should also be the same. Therefore redundancy gain for the two diagonals should be the same.

This assumption, however, is not essential to Garner's concept of integrality. His idea of two types of spaces, and in particular, his idea of a similarity space for integral dimensions, can remain viable even if we allow that this space has to be entirely empirically discovered rather than derived from unidimensional scales. That is, the similarity space can be regarded as "a reasonably regular distortion, a conformal mapping of the physical stimulus space just as the usual unidimensional scales are reasonably regular distortions of single physical dimensions" (Chipman and Carey, 1975, p. 423).

Predictions of rections time (RT) on correlated sorting by both Garner's and the compatibility theory will then be based on the same multidimensional scaling configurations , and the difference in reaction time between the two diagonals can be handled by this modified version of Garner's theory. Indeed, there is already some support for this modified version. Lockhead and King (1977) found distance between stimuli on a multidimensional scaling configuration to be a good predictor of performance.

Given this modification, the essential difference between the two theories then lies in the interpretation of the multidimensional scaling configuration. It lies in whether the similarity space is taken as psychologically real or whether it is the projected distances

along the relevant dimensions which are taken as psychologically real. In the second case, the model is only incidentally geometric.

Thus, we see that the difference in RT between the two diagonals need not be diagnostic of the two theories. Let us now turn to the correlation between the amount of interaction and the amount of interference.

The correlation, first of all, was not very high, even at its face value. Both subjects showed a correlation coefficient of .41 ($p > 1.0$) and only one subject showed no significant interference in the non-interactive set.

More basically, distance between stimuli was not controlled in Experiment II. In fact, one subject was reported to have a correlation of .82 between interference and relative discriminability. Relative discriminability was defined as the ratio of the average discriminabilities (interstimulus distances on a multidimensional scaling configuration) of relevant and irrelevant dimensions of a set of four stimuli. But discriminabilities along the relevant and irrelevant dimensions are exactly the variables Garner used to explain the presence of interference for integral dimensions. Because of this confounding, results from Experiment II cannot be interpreted as due to interaction or incompatibility. They might also be due to Garnerian integrality.

In Experiment III, in which relative discriminability was controlled, the amount of interaction had a consistent effect on sorting for only one subject, the subject whose non-interactive dimensions were $HR^{.8}$ and $AR^{.2}$; on the other hand, relative discrimina-

bility had a consistent effect on sorting for both subjects.

To summarize: 1) with the modification that the psychological similarity space is a reasonably regular distortion of the physical space, Garner's theory can accomodate the unequal sorting speeds of the diagonals. 2) Interaction did not consistently affect the amount of interference. 3) Relative discriminability did consistently affect the amount of interference.

In sum, the evidence supporting the separability of the domain is not strong. Lacking the establishment of this precondition, the compatibility theory remains to be validated.

Somers' (1978) solution to the problem of circular post hoc theorizing was to introduce the concept of rectangularity. However, by doing so, extra strain was imposed on the demonstration. Since the demonstration hinged at once on both compatibility and rectangularity, both concepts would have to work in order for the demonstration to succeed. There is some empirical evidence in the literature that suggests that the use of rectangularity as a dependent variable indicating compatibility will likely be problematic. Dissimilarity judgments of pairs of dimensions have been found to interact. Such dimensions included area and shape of rectangles (Chipman and Noma, 1979; Krantz and Tversky, 1975); loudness and pitch of noise bands (Chipman and Carey, 1975); jaggedness and size of random polygons (Chipman, mentioned in Chipman and Noma, 1979). In all these cases, an intensive dimension--size or loudness--seems to affect the perception of another dimension. If rectangularity is not a valid measure of compatibility, it obviously will not be a valid predictor of performance based on the

compatibility theory. Its use as an independent variable will not lead to orderly results.

This dissertation will tackle the problems one at a time. It will first attempt to validate the compatibility theory without recourse to the concept of rectangularity: it will attempt to show that physical dimensions compatible with psychological dimensions will not produce interference, while physical dimensions incompatible with psychological dimensions will produce interference. It will then separately examine whether or not rectangularity is a valid measure of compatibility.

At the same time, this dissertation will attempt to show that the relationship between two operations defining integral and separable dimensions--interference and condensation time-- and two phenomena that fall in between the concepts of integral and separable dimensions --degrees of integrality and asymmetric integrality--can result from the degree of compatibility between physical and psychological (i.e., separable) dimensions.

CHAPTER II

EXPERIMENT I: A VALIDATION

The purpose of this experiment is to validate the compatibility theory. It seeks to show that the presence of interference in orthogonal sorting need not imply any "integral" internal representation. Interference can occur in a separable domain. When physical dimensions manipulated do not correspond with psychological dimensions, there will be interference, caused by variability within a response category. The greater this psychological within-class variability, the greater the interference.

In order to demonstrate a case of interference due to incompatibility, two conditions must be met. First, the interference produced must not be explicable by Garnerian integrality. That is to say, effects due to Euclidean distance in a multidimensional similarity scaling configuration must be unconfounded.

Second, we must have available a psychophysically incompatible dimension, and most crucially, a psychophysically compatible dimension. We can then show that the compatible dimension produces no interference in orthogonal sorting, and that the incompatible dimension produces interference in an amount in accordance with the within-class variability it creates. Stimulus values along the

incompatible dimension can be converted into those along the compatible dimension. These converted values will indicate how much intraclass variability exists, and therefore how much interference will result.

The precision aimed at in this experiment is merely ordinal. We predict that, other things being equal, the more that stimuli within a category vary along the psychological dimension, the greater the interference. An interval level of precision requires a unidimensional psychophysical scale of the psychological dimension, which is neither readily available nor essential for the purpose of this experiment.

A third condition would be added to keep the complexity of the experiment within manageable bounds. Predictions would be based on within-class variability. Between-class variability would be kept constant by keeping the minimum between-class distance constant. This is a conservative measure. The reason is this: One of our goals is to show that greater within-class variability produces more interference. Suppose that average, rather than minimum, between-class distance is kept constant. Then the set of stimuli with greater within-class distance will inevitably have a smaller minimum between-class distance, by the definition of "average". This smaller minimum distance could conceivably be a cause of more interference. The results would then again be explicable by Garner's concept of integrality.

However, if the minimum distance between response classes is kept constant, all other measures of between-class distance, for example, average discriminability, are greater for sets with

greater within-class variability. Thus, any increase in interference for sets of stimuli with greater within-class variability cannot be ascribed to a decrement in some measure of between-class variability.

2.1 Selection of Task

Orthogonal sorting was the only speeded sorting task used in this experiment. Condensation was not used because it would not be particularly illuminating here, since condensation time was not clearly predictable with the sets of stimuli used in this experiment. It will be used in the second experiment. Correlated sorting was not be used, either here or in any of the ensuing experiments, for the reason that it is an undiagnostic task: as Garner (1974) noted, separable dimensions should produce no redundancy gain only if the stimuli are not more discriminable along the irrelevant dimension. Otherwise, for the obvious reason that subjects have the option of attending to what is designated the "irrelevant" dimension, there could be redundancy gain, when compared to performance on unidimensional sorting on the "relevant" dimension. This problem might be remedied by using the faster of the two unidimensional conditions as the control. However, even if the irrelevant dimension is not any more discriminable, a probabilistic model of parallel processing (Townsend, 1974) could still predict faster reaction time with redundant variation on separable dimensions.

Moreover, as mentioned in the Introduction, Garner's theory can readily be modified to hold different predictions on correlated sorting. For these reasons, redundancy gain is a less differentiating

measure than interference. Empirically, the two measures have not always converged. Dimensions which produced interference in orthogonal sorting sometimes produced redundancy gain (Garner and Felfoldy, 1970), sometimes did not produce redundancy gain (Pomerantz and Sager, 1975), and sometimes produced redundancy loss (Somers, 1978).

For these reasons, correlated sorting will be left out in this series of experiments.

2.2 Selection of Stimuli

As mentioned earlier, a crucial condition in setting up this experiment is that we have on hand a compatible dimension. A search in pilot studies for a compatible dimension suggests that this is not an easily met condition. Incompatible dimensions -- as indicated by the ubiquitous presence of interference -- have shown themselves relentlessly available. Here, in order to obtain a compatible dimension -- without taking up the extra burden of rectangularity -- we return partially to the original notion of separability based on compelling introspection.

We assume that, while other physical dimensions are varied, if a stimulus of a particular value along a certain physical dimension remains introspectively compellingly unchanged along this physical dimension, then this dimension is psychophysically compatible. The ability to perceive identity in the face of variation along other dimensions is taken to be a characteristic of an independent, or psychological, dimension. With such a dimension, one should see

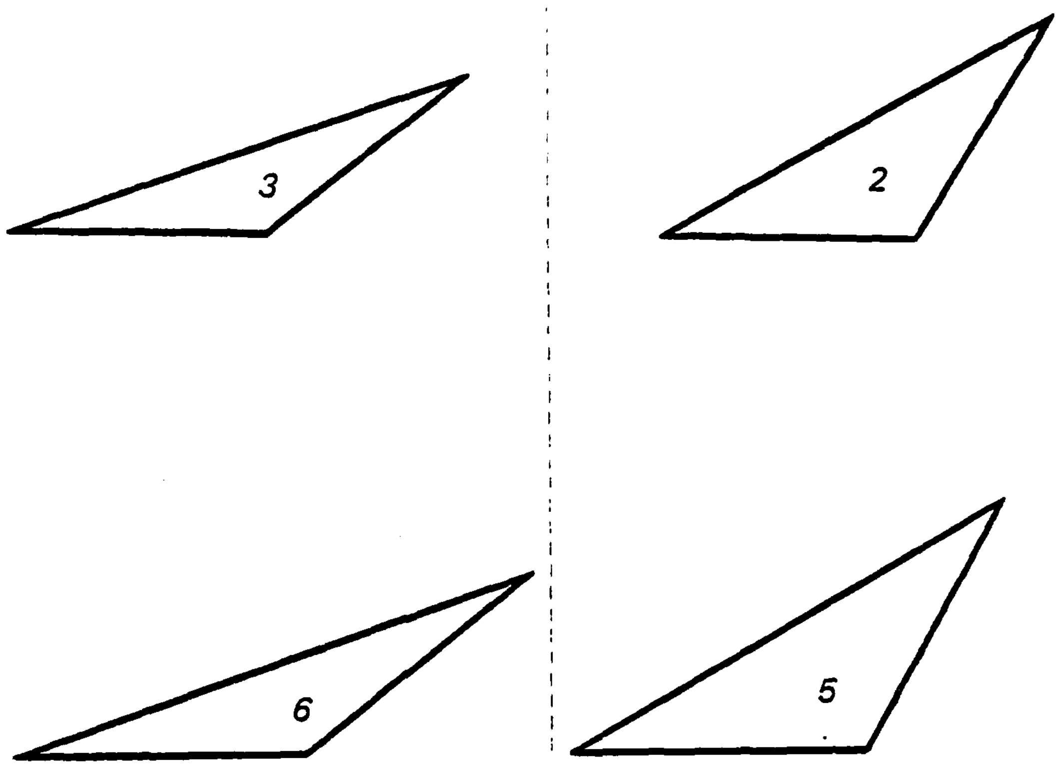
no within-class variability along the psychological dimension in an orthogonal sorting task, and thus should be able to sort without interference.

It should be evident that triangles that are geometrically similar are perceived to be the same in a certain respect, namely, shape. A set of triangles formed by the orthogonal combination of shape and another dimension is shown on Figure 3. Triangles in each column are geometrically similar. More will be said about the construction of these triangles later on. Thus, shape is hypothesized to be a compatible dimension. Any dimension different from shape but not orthogonally varied with it will be hypothesized to be incompatible.

Verification of the above two hypotheses will be sought in this experiment by means of performance on orthogonal sorting. Nevertheless, since introspection seems to be prevalently held in low-esteem, a justification for its use seems to be in order here. Any verification of the hypotheses may otherwise too strongly suggest a mere stroke of luck.

2.2.1 Justification of Introspection as Basis of Choice of Dimension

First, it should be noted that the type of introspection with which I am concerned here is different from the type Introspectionists engaged in. I in no way require any "analytical" separation of sensations from perceptions. Thus not all of the objections to introspection raised against the Introspectionists apply. Those



Triangle Number	Triangle Dimensions: α in degrees	R in 1/16 inch
2	61	22
5	61	25
3	39	22
6	39	25

Figure 3. Set of triangles formed by an orthogonal combination of α (the right exterior angle) and R (the length of right side). α is hypothesized to be a psychophysically compatible dimension. Dotted line denotes required partition of triangles.

that are relevant may be listed as follows:

1. There is disagreement among observers.

2. Observers are not outside the observed system; the act of observation may therefore disturb the content of what is to be observed.

3. Introspection cannot be objectively described among observers; it is a subjective experience.

The last two objections have been dealt with by Kohler (1947, Ch. 2). As for the problem of disagreement among observers, it is not a problem in the case of this experiment. The introspected phenomenon -- that geometrically similar triangles look the same shape -- is compelling. Thus, none of the objections is valid in this case.

It is realized that, whereas disagreement among observers is fatal to the viability of the method in that particular instance, agreement *per se* does not imply the viability of the method, or guarantee the validity of that specific instance of introspection. Consider, for example, the introspection of the blindspot. Observers agree that we perceive no hole corresponding to the blindspot. That introspection is fallible, however, should not lead to a blanket dismissal of it as a source of information. Like all other hypotheses, those based on introspection should be held until they are contradicted by reliable data and until a better hypothesis emerges. Contrary to the impression of crudeness introspection might give, it is not unscientific to base a hypothesis on introspection, when it is not contradicted by data and not yet replaceable by a better hypothesis using a better source of information.

Indeed, until then, it would be unscientific for us to disregard hypotheses based on introspection.

The merit of a method should be judged in the context of the state-of-the-art by its heuristic value. Under the knowledge available at a certain time, will the use of a certain method move us forward, will it provide us with the basis for further advance? Once we obtained preliminary confirmation of our hypothesis or theory, we can go on from there to develop more accurate, more widely applicable, and more reliable methods of measurement. Specifically, once we have validated the compatibility theory based on the hypothesis that shape is a psychological dimension, we can then go on to examine, for instance, characteristics of multidimensional configurations of stimuli that are of the same shape -- whether these configurations are rectangular, whether they have parallel lines, and so on. And from there we may begin to generalize to other dimensions which may not be as introspectively compelling.

2.2.2 Construction of Sets of Stimuli

A word will be said about how the sets of stimuli in this experiment-- triangles-- were constructed. For reasons laid out by Somers (1978), these triangles were right-leaning with a horizontal base. The sets were formed by orthogonal combinations of two dimensions. However, the specification of a triangle requires three dimensions, disregarding its orientation and position in space, which were kept constant by fixing a horizontal base in fixed positions on

a cathode -ray-tube (CRT). That is, one of the three dimensions needed to be kept constant. Somers did so by fixing the length of the base. This restriction created a critical problem: shape could no longer be independent of any dimension. A little manipulation of triangle parameters will show that the shape of a triangle now inevitably varies along with any variation in any dimension. If the phenomenologically compelling dimension of shape is indeed the most salient psychological dimension, then this restriction has effectively precluded the discovery of a psychological dimension. No independent variable under this restriction is a good independent variable. We have tied our own hands.

In this experiment, instead of keeping the length of the base constant, we kept the ratio of the base and right side constant (base/right side = 1). This restricted the number of varying dimensions to two, and yet allowed shape to be independent of any dimension.

2.3 The Experiment

To recapitulate, this experiment seeks to show that the presence of interference in orthogonal sorting need not imply any "integral" internal representation, that interference can occur in a separable domain. The domain will be shown to be separable by the existence of a dimension that, besides being phenomenologically compelling, produces no interference. Any physical dimension incompatible with this psychological dimension will produce interference, due to the

within-class variability it creates along the dimension of shape. It will be shown that the greater this dimensional within-class variability, the greater the interference.

The experiment is divided into two parts. The first part attempts to show that shape -- a hypothetically compatible dimension -- produces no interference, whereas height -- a hypothetically incompatible dimension -- does produce interference. The second part attempts to show that length of left side -- another hypothetically incompatible dimension -- also produces interference, and that the greater the within-class variability it produces along the dimension of shape, the greater the interference.

2.3.1 Method

2.3.1.1 Subjects. The subjects were two paid undergraduate students at the University of Michigan. One was 19 years old; the other 20. Both had normal vision. Neither had any previous experience with the tasks used in this study.

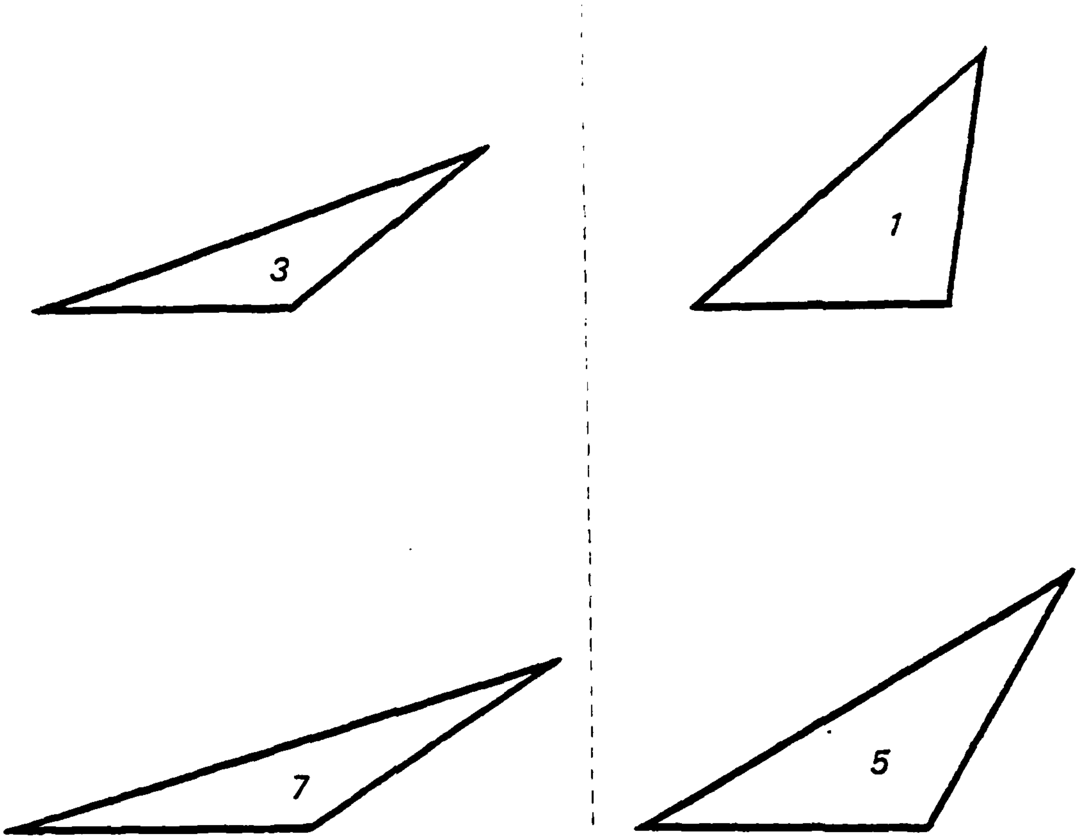
2.3.1.2 Stimuli. The stimuli specific to each of the two parts will be described separately. Dimensions are designated relevant or irrelevant according to their role in the sorting task. The compatibility of the relevant dimensions alone needs to be considered. The irrelevant dimension, to be varied orthogonally with the relevant one, was the length of the right side (R) of a triangle throughout this experiment. The stimuli were right-leaning isosceles triangles with a horizontal base. The lengths of the base and the right side

were equal. The triangles were presented on a CRT screen controlled by a PDP-1 computer. They ranged from 2.7 to 14.3 degrees of visual angle horizontally and from 1.2 to 2.0 degrees vertically.

2.3.1.2.1 Part One: Two sets of triangles were constructed by the orthogonal combinations of 1) the right exterior angle (α) and R (see Figure 3) and 2) the height (H) and R (see Figure 4). Since these were isosceles triangles, α, or any of the equivalent specifications, uniquely specified the shape of the triangles. The dimension α was hypothesized to be a compatible dimension; height, a dimension different from shape and not varied orthogonally with it, was hypothesized to be incompatible. The values of the triangles along the dimensions involved are listed in each figure. The numbers referring to the triangles are nominal. Dotted lines denote the required partition of sets. The difference between the two sets of triangles in within-class variability should be evident.

To ensure that any difference in interference between the two sets is not due to differences in overall, rather than dimensional, within-class similarity--a possible Garnerian explanation-- a control set for each of the two sets mentioned above (designated as experimental) was created. Each control set was matched with its experimental set on their α values, but the variation along the irrelevant dimension R was made greater, i.e., the difference in "size" was made greater. The overall similarity between triangles in the same category was thus decreased. The values of these stimuli are listed in Tables 1 and 2. If inter-

ference is due to the triangles being encoded in integral dimensions, the Euclidean within-class distance should affect the amount of interference, leading to the prediction that the control sets should produce more interference than the experimental sets.



Triangle Number	H in 1/16 inch	R	α
	Triangle Dimensions		
1	22	22	82
5	22	25	61
3	14	22	39
7	14	25	33

Figure 4. Set of triangles formed by an orthogonal combination of height (H) and length of right side (R). Height is hypothesized to be an incompatible dimension.

Table 1

Control set for α x R set in Experiment 1: stimulus values

	Dimension	
stimulus number	α(in degrees)	R(in 1/16 inch)
2	61	22
8	61	28
3	39	22
9	39	28

Table 2

Control set for H x R set in Experiment 1: stimulus values

	Dimension	
stimulus number	α(in degrees)	R(in 1/16 inch)
1	82	22
8	61	28
3	39	22
10	33	28

The minimum between-class variation in angle was kept constant for all four sets -- between 39^{o} and 61^{o}.

2.3.1.2.2 Part two: Two sets of triangles were constructed by the orthogonal combinations of length of left side (L) -- an incompatible, relevant dimension -- and R. As L varies, two sets with differing within-class variability in shape were created. (See

Figures 5 and 6.) The stimulus values of these triangles are listed in the figures.

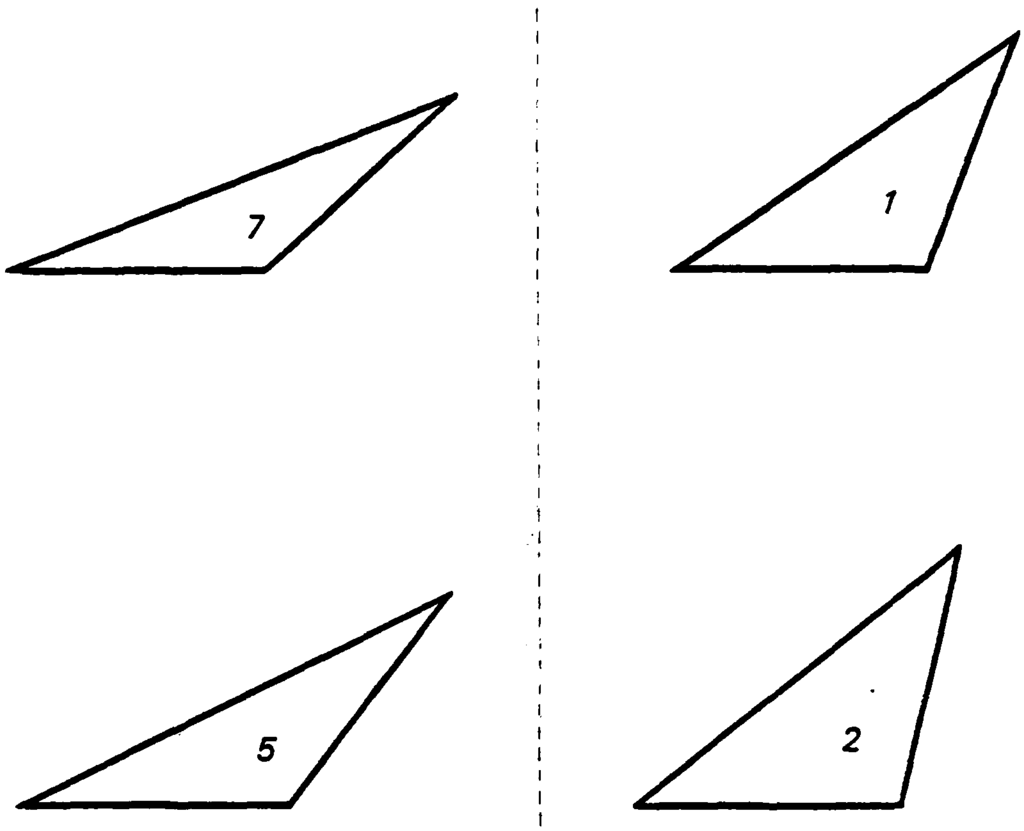
As in Part One, to ensure that any difference in the amount of interference between these two sets was not due to Euclidean distance, a control set was created for each of the above experimental sets. Each control set has the exact same values along α as its experimental set, but the values along the irelevant dimension -- R, roughly corresponding to "size" -- were increased for two of the triangles such that the overall similarity between triangles of the same category was decreased, i.e., the Euclidean distance between stimuli of the same class was increased. The stimulus values of the control sets are listed in Tables 3 and 4.

Table 3

Control set for L x R set with small within-class variability in Experiment 1: stimulus values

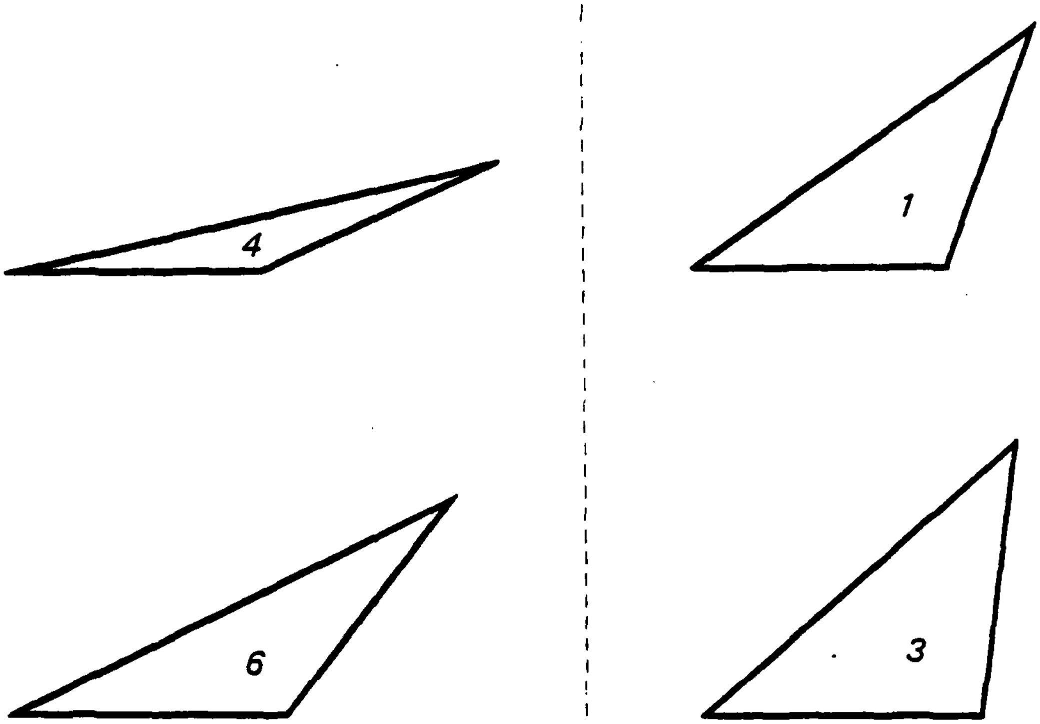
	Dimension	
stimulus number	R(in 1/16 inch)	α(in degrees)
1	22	70
7	22	43
8	26	77
9	26	53

If the dimensions R and α are integral, Euclidean distance should affect the amount of interference, leading to the prediction that the control sets should produce more interference than the experimental sets.



Triangle Number	Triangle Dimensions: L in 1/16 inch	R	α
1	36	22	70
2	36	23	77
7	41	22	43
5	41	23	53

Figure 5. Set of triangles formed by an orthogonal combination of length of left side (L) and R: small within-class variability.



	Triangle Dimensions		
Triangle Number	L	R	α
1	36	22	70
3	36	24	83
4	43	22	25
6	43	24	53

Figure 6. Set of triangles formed by an orthogonal combination of L and R: large within-class variability.

Table 4

Control set for L x R set with large within-class variability in Experiment 1: stimulus values

	Dimension	
stimulus number	R	α
1	22	70
4	22	25
10	29	83
12	29	53

The minimum between-class difference in α was kept constant for all four sets -- between 53^{o} and 70^{o}.

2.3.1.3 Procedure

The procedure described here is general for all experiments in this study. Specifics of each experiment will be pointed out as I proceed.

There were two tasks: dissimilarity judgment and speeded sorting. Each was performed by each subject a number of sessions, varying from experiment to experiment.

In the dissimilarity judgment task, subjects were instructed to rate the overall dissimilarity of pairs of triangles. Full instructions, reproduced in Appendix A, were given at the beginning of the first two sessions. Each session lasted about 50 minutes. The number of blocks within each session varied between four and

seven from subject to subject. Each block required dissimilarity judgments on all possible pairs of sixteen triangles. The choice of the number of triangles was based on the consideration of avoiding non-unique solutions in multidimensional scaling. Since not all experiments had as many as sixteen stimuli, stimuli in those that did not -- Experiment I and Experiment III -- were grouped together in the dissimilarity judgment task.

After an initial familiarization with the triangles in the set, presented one at a time in random order, the subject was presented with each of the 120 possible pairs of sixteen triangles, presented one pair at a time in random order. The subject, by pushing one of ten microswitches numbered from one to ten from left to right on a panel, rated the dissimilarity of each pair. The task was self paced. At the end of each block, there was a rest period of about two minutes.

In the speeded sorting task, subjects were required to sort triangles into two categories. Full instructions, reproduced in Appendix B, were given at the beginning of the first two sessions. The number of sessions varied from experiment to experiment. The number of blocks within each session also varied, depending on the length of the block. Each session lasted from 40 to 60 minutes. The number of sets of triangles to be sorted in each block varied from experiment to experiment. However, the number of runs of each set of triangles remained constant throughout. There was always one practice run, if the subject was new, plus two actual runs. The sets of triangles to be sorted were randomly ordered within

each task.

Subjects sorted the triangles -- presented on the center of a CRT screen -- into two categories by pressing with their left or right index finger on one of two microswitches on a panel. Before each task, instructions for sorting a particular set of triangles -- either two or four of them -- were presented in still frames on the CRT screen. These instructions displayed one triangle of the set at a time, accompanied by the word "Left" or "Right", corresponding respectively to the response categories of pressing the left or right response key. For each set, there were always 12 practice trials followed by 40 actual trials. Since the number of triangles differed across sets, this implied that the number of presentations of each triangle also differed across sets. For sets with two triangles -- the unidimensional condition used as a baseline -- there were 20 actual presentations of each triangle. For sets with four triangles, there were only ten of each.

Subjects were instructed to respond as quickly as possible while keeping error rate below 3%.

In part one of Experiment I, each subject had one practice session followed by two actual sessions of dissimilarity judgments on triangles in part one -- listed in Figures 3 and 4, and Tables 1 and 2 --and those in Experiment III, part one. Triangles in part one of Experiment III were chosen to be grouped here because the two parts have many triangles in common. Subjects then had one practice session followed by an actual session of sorting. Each sorting session consisted of two blocks. Each block consisted of one run of ten

tasks: four orthogonal -- two experimental and two control -- and six unidimensional tasks. As mentioned earlier, the sets were randomly ordered within each block.

Part two followed the same procedure, except that there were no practice sessions since the subjects were the same ones in part one. For the dissimilarity judgment task, the triangles in part two -- listed in Figures 5 and 6 and Tables 3 and 4 -- were grouped with those in Experiment III, part two, for the same reason mentioned above.

2.3.1.4 Results and Discussion

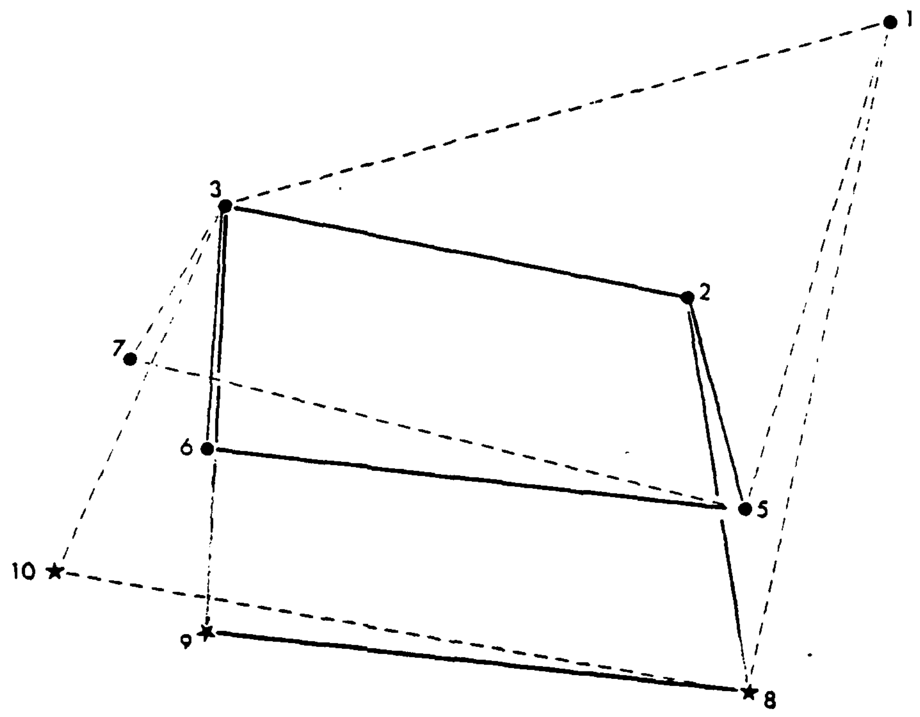
2.3.1.4.1 Results and Discussion: Part one: Compatible and Incompatible Dimensions. Results on dissimilarity judgments and speeded sorting will be described separately.

2.3.1.4.1.1 Dissimilarity Judgments. Dissimilarity judgments given by each subject for each stimulus pair were averaged. The first subject, S.L., rated each pair a total of 11 times in two sessions; the second subject, C.H., a total of 10 times. The mean ratings for each subject were submitted to multidimensional scaling using the nonmetric multidimensional scaling program CONSCAL (Noma and Johnson, 1977; also see Somers and Pachella, 1977; and Somers, 1978, for examples of its use). The program -- using distance as a model of dissimilarity -- finds a geometrically represented solution of the lowest stress to a set of similarity or dissimilarity data. Stress is a measure of the poorness of fit of a solution to the data. The

program also finds the stress of a specified geometric representation to a given set of data. The stress of this specified solution and a comparison of the increase in stress from the first to this specified solution provide two ways of evaluating the goodness of fit of a given set of data to a specified solution.

The configuration of lowest stress for subject S.L. is shown on Figure 7. Recall that stimuli in this part of the experiment were grouped with those in Experiment III in the dissimilarity judgment task. The stress for the entire set of 16 stimuli was .04, which is fairly low in comparison with other stresses obtained for 16 stimuli (Brown and Andrews, 1968; Somers, 1978). As can be seen from the figure, each control set had a longer within-class interstimulus distance than its corresponding experimental set, as expected. The increase in within-class interstimulus distance from the two compatible sets (α by R) to the two incompatible sets (H by R) was comparable to that from the two experimental sets (short Euclidean distance) to the two control sets (long Euclidean distance), with the former slightly less than the latter.

The scaling solution for the second subject was degenerate. The solution showed groups of stimuli collapsing into several single points, with a stress so low as to be highly unlikely. However, an examination of the individual pairwise ratings showed that stimuli within a category were rated less similar in each control group than in its corresponding experimental group. The mean dissimilarity ratings for the stimulus pairs (2,5), (3,6), (2,8), (3,9), (1,5), (3,7), (1,8) and (3,10) were respectively 2.5, 2.7, 3.5, 4.1, 5.6, 2.9, 5.8 and 4.5. The increase in



●———● 2-5-6-3 Set of triangles formed by an orthogonal combination of R and α : compatible

●- - - -● 1-5-7-3 Set of triangles formed by an orthogonal combination of R and H : incompatible

●———★ 2-8-9-3 Control set for 2-5-6-3 in test of effect of Euclidean distance

●- - - -★ 1-8-10-3 Control set for 1-5-7-3 in test of effect of Euclidean distance

Figure 7. Multidimensional scaling configuration of lowest stress for subject S.L.: Experiment I (Part One).

within-class overall similarity from the two compatible sets to the two incompatible sets was comparable to that from the two experimental to the two control sets, with the former slightly greater than the latter. As long as relations in overall similarity satisfy the design of the experiment, the failure in obtaining an undegenerate geometric representation does not have any critically detrimental effect on the validity of the experiment.

If interference is due to Euclidean interstimulus distance, that is, if the internal representation is "integral", then all sets should show some interference; the incompatible sets should show greater interference than the compatible sets, and the control sets should show a comparably greater amount of interference than the experimental sets, since the control sets showed a comparable increment in Euclidean distance over the experimental sets as the incompatible over the compatible sets.

If interference is instead due to dimensional interstimulus distance (along α in this case), then the compatible sets should show no interference, and the control sets should show no more interference than the experimental sets.

<u>2.3.1.4.1.2 Speeded Sorting Performance</u>. Mean error rates were low: 1% for subject S.L. and 4% for subject C.H. Correlations between RT for correct responses and errors were high: they were .7 for S.L. and .8 for C.H., $\underline{p} < .05$. For ease of analysis, RT's for errors were included in the analysis.

Due to the unbalanced design -- orthogonal sets had twice as many stimuli as the unidimensional sets -- results were

analyzed in two separate steps. First an analysis of variance was run with subject (S) x task type (T) x stimulus set defined by Euclidean distance (E) x stimulus set defined by dimensional distance (D). The analysis of variance table is given in Appendix C. Then a more detailed analysis of variance was run separately on the data from each task (orthogonal and unidimensional), with the factors S, E, D, run (R), stimulus(St), and trial(Tr), for the orthogonal task; and the factors S, R, stimulus set (G), St, interstimulus distance (I) and trial for the unidimensional task. St was nested within E x D for the orthogonal task, and within G x I for the unidimensional task. The analysis of variance tables for the separate tasks are given in Appendix D.

Contrasts averaged over the two subjects were evaluated by using as an estimate of error the mean square for the interaction between S and the factors involved. For instance, the error term for the difference in the amount of interference between stimulus sets with different Euclidean interstimulus distances was S x T x E. To ascertain that averaged performance reflects individual performance, results of each subject were also looked at individually, using the main effect of Trials (nested within stimuli, pooled across task types) as the error term. Since the degrees of freedom are already large (See Appendix D), not much could be gained by pooling this error term with interaction terms.

The amount of interference is defined by the difference between the mean RT's for the orthogonal and the unidimensional tasks. Averaged over two subjects, the compatible dimension produced a

small and insignificant amount of interference -- 9±10 msec, $p > .05$. Unless otherwise stated, error margins given are 95% confidence intervals. The incompatible condition produced a significant amount of interference -- 44±10 msec. The difference in interference between these two conditions was 35±14 msec.

The experimental sets produced 32±17 msec of interference, the control sets 21±17 msec. The difference between them was -11±24 msec. (Differences in the direction opposite to what might be expected are preceded by a minus sign). Thus, Euclidean inter-stimulus distance did not affect the amount of interference.

The results of individual subjects reflected the same pattern. Amounts of interference for each subject under each condition are tabulated in Table 5.

Table 5

Experiment *I*: Part One: Interference (in msec) for individual subjects under various conditions

Subject	Condition	
	compatible	incompatible
S.L.	5	46*
C.H.	13	42*
	experimental (short Euclidean within-class distance)	control (long Euclidean within-class distance)
S. L.	25*	26*
C. H.	39*	16

Note. Asterisks denote contrasts that are significant at the .05 level using the Scheffe procedure. The 95% Scheffe simultaneous confidence interval for contrasts listed in this table is ±18 msec.

The amounts of interference obtained for both subjects under the compatible condition were insignificant, $p>.05$ using the Scheffe procedure. For both subjects, the incompatible condition produced significant amounts of interference and when compared to the compatible condition, produced more interference; the difference was 41 ± 25 msec for S.L. and 29 ± 25 msec for C.H. Error margins given for results of individual subjects are 95% Scheffe simultaneous confidence intervals.

In contrast, Euclidean within-class interstimulus distance did not consistently or significantly affect the amount of interference. The difference in interference between the experimental and the control sets was 1 ± 25 msec for S.L. and -23 ± 25 msec for C.H. As will be seen in conjunction with results in part two, the direction of the effect, if any, of Euclidean distance was consistent across neither subject nor condition.

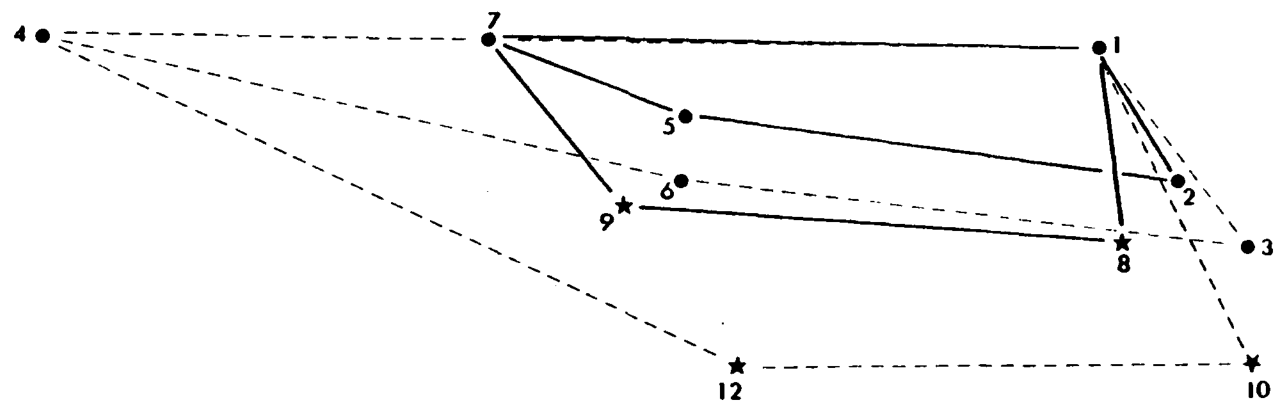
In conclusion, speeded sorting results supported our hypotheses that shape was a psychological dimension, which produced no interference in orthogonal sorting, and that a dimension incompatible with the psychological dimension would produce within-class variability, which in turn would produce interference. Thus, the presence of interference cannot be taken as an indication of "integrality", of internal representation in a Euclidean similarity space.

We have hypothesized, on the basis of introspection, that shape was a psychological dimension. On the basis of this assump-

tion, together with the compatibility theory, we have hypothesized a pattern of results on speeded sorting, which was verified. To say that both of these hypotheses were supported may suggest to some a case of eating-your-cake-and-having-it-too. However, it is not. Since the demonstration of the compatibility theory hinged on both hypotheses, its failure would be a refutation of either or both hypotheses, but its success is a verification of both.

2.3.1.4.2 Results and Discussion: Part Two - Incompatible dimension with two levels of within-class variability. Analyses paralleled those in part one.

2.3.1.4.2.1 Dissimilarity Judgments. S.L. rated the dissimilarity of each pair of triangles 11 times. The multidimensional configuration of his data is shown on Figure 8. This configuration was obtained with the ordering of the stimuli constrained along α and R, allowing for the breaking of ties. The unconstrained solution was degenerate. Even so, the stress for the constrained solution for the set of 16 stimuli of which those in Figure 8 are a subset is only .05, which is fairly low, indicating that the configuration is a reasonable fit to the data. As can be seen from the figure, each control set had a longer within-class interstimulus distance than its experimental set, as expected. The increase in within-class Euclidean interstimulus distance from the sets with small -- (1, 2, 5, 7) and (1, 8, 7, 9) -- to large -- (1, 3, 4, 6) and (1, 10, 4, 12) -- dimensional within-class distance was large compared to that between the experimental and the control sets. Assuming the



●——● 1-2-5-7 Set of triangles formed by an orthogonal combination of L and R: small within-class variability

● - - -● 1-3-6-4 Set of triangles formed by an orthogonal combination of L and R: large within-class variability

★——● 1-8-9-7 Control set for 1-2-5-7 in test of effect of Euclidean distance

★- - -● 1-10-12-4 Control set for 1-3-6-4 in test of effect of Euclidean distance

Figure 8. Constrained multidimensional scaling configuration for subject S.L.: Experiment I (Part Two).

distances to have ratio properties, the change in Euclidean distance between the experimental and control sets was only about 1/5 of that between the other sets. The implication of this will be discussed later.

C.H. rated the dissimilarity of each pair of triangles 8 times. The multidimensional scaling configuration of this subject's data did not produce an undegenerate solution. However, an examination of the individual pairwise ratings again showed that within-class similarity was higher in each experimental group than in its corresponding control group. The mean dissimilarity ratings for the pairs (1, 2), (1, 8), (5, 7), (7, 9), (1, 3), (4, 6), (1, 10) and (4, 12) were respectively 2.4, 3.9, 3.8, 5.3, 4.0, 7.9, 6.8 and 8.3. Assuming these ratings to have ratio properties, the increase in dissimilarity from the experimental to the control sets is slightly more than half of that between the sets with small dimensional within-class variability and those with large dimensional within-class variability.

The relative smallness of this change in overall similarity between the experimental and control groups implies the possibility that changes in Euclidean distance can account for the increase, if any, in interference from the sets with small dimensional within-class variability to those with large within-class variability. Lack of increase in interference from the experimental to the control sets could be due to the relative smallness of the change in Euclidean distance. In short, the possibility of a Euclidean spatial internal representation is left open.

2.3.1.4.2.2 Speeded Sorting Performance. Mean error rates were low: 1% for S.L. and 3% for C.H. Correlations between RT's for correct responses and errors were high. They were .7 for S.L. and .8 for C.H., $p<.05$. For ease of analysis, RT's for errors were included in the analysis.

The analyses of variance tables are shown in Appendices E and F.

Averaged over the two subjects, the sets with small dimensional within-class variability produced 43±19 msec of interference. Those with large dimensional within-class variability produced 79±19 msec of interference. The difference of 33±27 msec is significant. The experimental sets produced 70±25 msec of interference; the control sets 49±25 msec. The difference (-21±24 msec) is not significant. That all stimulus sets produced interference is consistent with the hypothesis that L is an incompatible dimension.

Results of individual subjects reflected a similar pattern. Amounts of interference for each subject under each condition are tabulated in Table 6.

Table 6

Experiment I: Part Two: Interference (in msec) for individual subjects under various conditions

Subject	Condition	
	small dimensional variability	large dimensional variability
S.L.	18	64*
C.H.	68*	88*
	experimental (small overall variability)	control (large overall variability)
S.L.	61*	21
C.H.	79*	75*

Note. Asterisks denote contrasts that are significant using the Scheffe procedure. The 95% Scheffe simultaneous confidence interval for contrasts listed in this table is ±22 msec.

Most of the sets showed a significant amount of interference. Sets with greater dimensional within-class variability produced more interference for both subjects, although this difference did not reach significance by the Scheffe procedure for C.H.

The difference in interference between the experimental and the control sets was -40±31 msec for S.L. and 4±31 msec for C.H. There is no apparent reason why the control set should produce greater interference for S.L. The same contrast in part one was 1±25 msec for S.L., and -23±25 msec for C.H. As mentioned before, the effect of Euclidean distance was consistent neither across subject nor across experimental and control conditions.

Thus, from this part of the experiment alone, it may be at least, and unfortunately at most, concluded that a change in Euclidean within-class interstimulus distance of the magnitude involved between the experimental and control groups did not have any consistent effect on interference. The increase in interference from the sets with small dimensional variability to the sets with large dimensional variability is consistent with the compatibility theory. It may, however, also be due to a change in Euclidean distance , although this interpretation is quite unlikely given the results obtained in part one. This interpretation is also unlikely given the results obtained in the following experiment, which ruled out the hypothesis that triangles are encoded integrally.

2.3.1.5 Summary

Results in both parts of the experiment were consistent with the compatibility theory. The first part demonstrated that interference in orthogonal sorting could occur in a domain that is not internally represented as a Euclidean space. Euclidean interstimulus distance did not predict sorting performance. However, dimensional interstimulus distance did. There was no interference when a physical dimension manipulated (shape of triangle) corresponded with the psychological dimension. But there was interference when a physical dimension manipulated (height of triangle) was incompatible with the psychological dimension (shape of triangle). In part two, overall similarity between critical pairs of triangles was not well-controlled enough to allow an independent and unambiguous verification of the compatibility theory. The ambiguity of the design leaves open the possibility that interference was caused by an "integral" internal representation. The results, however, were consistent with the compatibility theory, and if a hypothesis verified in both part one of this experiment and Experiment II is accepted and taken into consideration--the hypothesis that the stimulus domain of triangles is dimensionally represented -- which is notan unreasonable thing to do since the same stimulus domain was involved, then the results in part two provided a further validation of the compatibility theory. They verified the predictions that a psychophysically incompatible dimension (left side of triangle) would produce interference, and that the greater the dimensional within-class variability created by

this dimension, other things being equal, the greater the resultant interference.

CHAPTER III

EXPERIMENT II: A TEST OF THE SUFFICIENCY OF RECTANGULARITY AND A CASE OF DEGREES OF INTEGRALITY

In this chapter and the next, I will examine the concept of rectangularity first theoretically and then empirically to clarify its connection with the compatibility theory. Both rectangularity and the compatibility theory assume that psychological dimensions are independent. With this critical property in common, rectangularity might appear to be a reasonable criterion of compatibility. However, as noted in the Introduction, empirical evidence supporting the hypothesis of rectangularity is not strong. If rectangularity is in some ways theoretically inconsistent with the compatibility theory, then with regard to this theory, rectangularity will not be a valid measure and hence will not be a successful predictor.

This experiment has four distinct purposes which are woven together by the compatibility theory: to test whether rectangularity is sufficient to indicate compatibility, to once more demonstrate in support of the first experiment that internal representation of triangles is dimensional, to demonstrate a case of degrees of integrality due to incompatibility, and to show that the converging operations

of condensation and interference in orthogonal sorting defining integral and separable dimensions (Garner, 1974) are explicable by the compatibility theory.

The basic design of the experiment was to compare speeded sorting performance for two sets of stimuli -- again, triangles. Each of these sets had a rectangular multidimensional scaling configuration that was oriented at an angle to each other. Performance was observed on two speeded sorting tasks: first, interference in orthogonal sorting, again using unidimensional sorting as the baseline; second, RT in a task termed diagonal sorting in this study. As the name implies, the task requires sorting stimuli at the ends of one diagonal of a rectangular configuration into one category against those of the other diagonal. This task has often been called condensation (Gottwald & Garner, 1975; Posner, 1964). The task requires condensing information along two dimensions defined by the experimenter. Since experimenter-defined dimensions are not necessarily those used by the subject, the term "diagonal sorting" which is free of processing connotations will be used here instead.

Let us consider predictions on the pattern of performance based on three models:

1. Triangles are represented internally as in a Euclidean space, so that orientation should not be a factor determining sorting performance. Any difference in performance is due to the discriminability of the rectangular sets. The greater the discriminability along the relevant dimension, the less the interfer-

ference; and the less the discriminability along the irrelevant dimension, the less the interference. The ratio of discriminability along the relevant and irrelevant dimensions will be defined as relative discriminability, as in Somers (1978). It should be inversely related to the amount of interference. It is not clear how relative discriminability will affect condensation. It is clear, however, that whatever effect it has should be independent of the orientation of the rectangular configuration, as is the case for interference.

2. Triangles are represented dimensionally. These dimensions are for any given subject stable unless learning takes place. Then according to the compatibility theory, the orientation of the rectangular configuration will affect sorting performance. A set of stimuli whose rectangular axes correspond with the psychological dimensions will show no interference and at the same time show slow diagonal sorting. Note that this pattern was part of the operational definition for separable dimensions (Garner, 1974). As the orientation of the rectangular configuration departs from that of the psychological axes, according to the present model, within a certain range of orientations, there will be more interference and at the same time faster diagonal sorting. Note that the presence of interference and a relatively short diagonal sorting time were part of the operational definition for integral dimensions (Garner, 1974). If the pattern of orthogonal and diagonal sorting performance defining separable and integral dimensions is indeed to be explained by a dichotomy of structures, then the gradations in between, the degrees of integrality, are quite inexplicable.

To see why orientation, according to the postulate of stable axes and the compatibility theory, could have such an effect on sorting performance, consider the rotation of a rectangular configuration in a psychological space with fixed axes (see Figure 9). The dotted line denotes the required partition of stimuli in orthogonal sorting. Dashed lines are projections onto the psychological dimension X.

The wider Q is, the easier the orthogonal sorting and the harder the diagonal sorting; conversely, the wider P is, the harder the orthogonal sorting and the easier the diagonal sorting. The reason is: for the orthogonal task, P indicates the dimensional within-class variability, and Q the dimensional between-class variability. Conversely, for the diagonal task, Q indicates the dimensional within-class variability for one of the response classes, and P indicates the dimensional between-class variability. To optimize performance on the diagonal sorting task, subjects could presumably when appropriate divide the stimuli into two classes -- extremes and those in between.

Consider a range of rotation from the orientation where P equals zero to that where Q equals zero. As P increases, Q decreases. Thus, as the set is rotated counterclockwise between the above-mentioned orientations, the orthogonal sorting task becomes harder and harder while the diagonal sorting task becomes easier and easier. Clockwise rotation should produce analogous results.

3. A conceivable variant of the second model is that internal representation is dimensional, and yet the dimensions could be constantly redefined depending on context. This model might predict that as

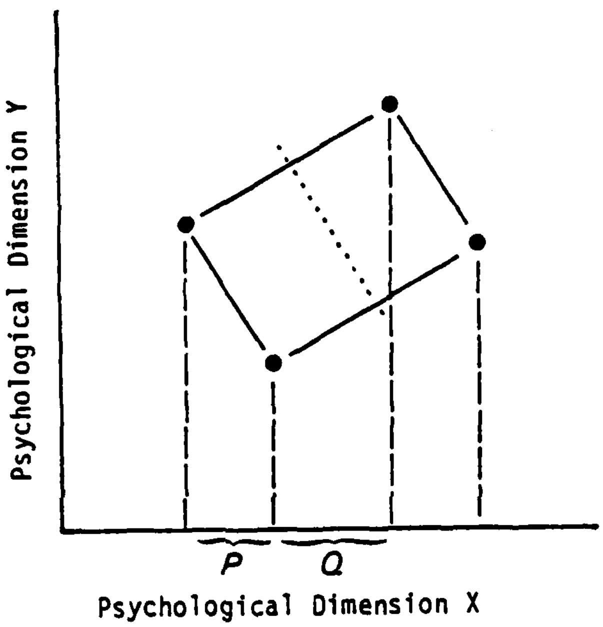


Figure 9. An explanation of an inverse relationship between the amount of interference and diagonal sorting time. Dotted line denotes required partition of stimuli; dashed lines denote projections onto the X-axis.

long as dimensions are orthogonal to each other, there will be no interference, regardless of orientation. This model, though conceivable, is rather messy, in the sense that "integral" and "separable" representations, even if theoretically distinct, would have few distinguishable empirical predictions. As we have argued, the converging operations defined by Garner (1974) -- difference in metric (see Pachella, Somers, and Hardzinski, 1980), redundancy gain in correlated sorting, interference in orthogonal sorting, and condensation performance -- are not diagnostic of "separable" and "integral" dimensions. There is one other operation: free sorting, which is seldom used. But even this single remaining member of the no longer converging set appears to be ambiguous. Kemler and Smith (1979) found that in general, subjects tended to use dimensional rather than similarity relations in a concept learning task based on the same rationale as free sorting, even with stimuli varying in the ostensibly "integral" dimensions of brightness and saturation. If in addition to all these operations being ruled out, the orientation of the axes for "separable" dimensions is unimportant, then the only theoretical difference between "integral" and "separable" dimensions is in whether Euclidean distances predict performance, or whether dimensional distances (projected or converted distances on the psychological dimension) predict performance. However, except in cases where the axes of the configuration happen to be orthogonal, when the psychological dimensions can be constantly redefined by the orientation of a stimulus configuration, it is not clear what the psychological dimensions are. Thus it would make no sense to talk about projected or converted dimen-

sional distances.

Thus, other than its prediction for this experiment, this model does not seem capable of generating any verifiable predictions. Its prediction for this experiment is: rectangular configurations will produce no interference, regardless of orientation.

3.1 Method

3.1.1 Subjects. Subjects were two undergraduates at the University of Michigan paid for their participation in the experiment. One was 20 years old; the other 21. Both had normal vision. Neither have had any experience with tasks in this study.

3.1.2 Stimuli

For each subject, the stimuli were two sets of triangles, 8 in each set, with some overlap. The multidimensional configurations derived from the dissimilarity judgments of each subject for each set were roughly rectangular, and the axes of each set were oriented at an angle to each other. The configurations of the lowest stress for 16 stimuli for the two subjects appear on Figure 10.[1] The values of these triangles are listed in Appendix G. The minimum stresses were .086 for D.B. and .047 for R.H. When each of the two columns of three adjacent quadrilaterals was constrained to be exactly rectangular, the stresses were .091 and .093 for D.B., and .054 and .057 for R.H. Since the minimum stresses were quite low, and the increases in stress from the con-

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[1] Extra stimuli not depicted in the figure were added such that the total number of stimuli was always 16.

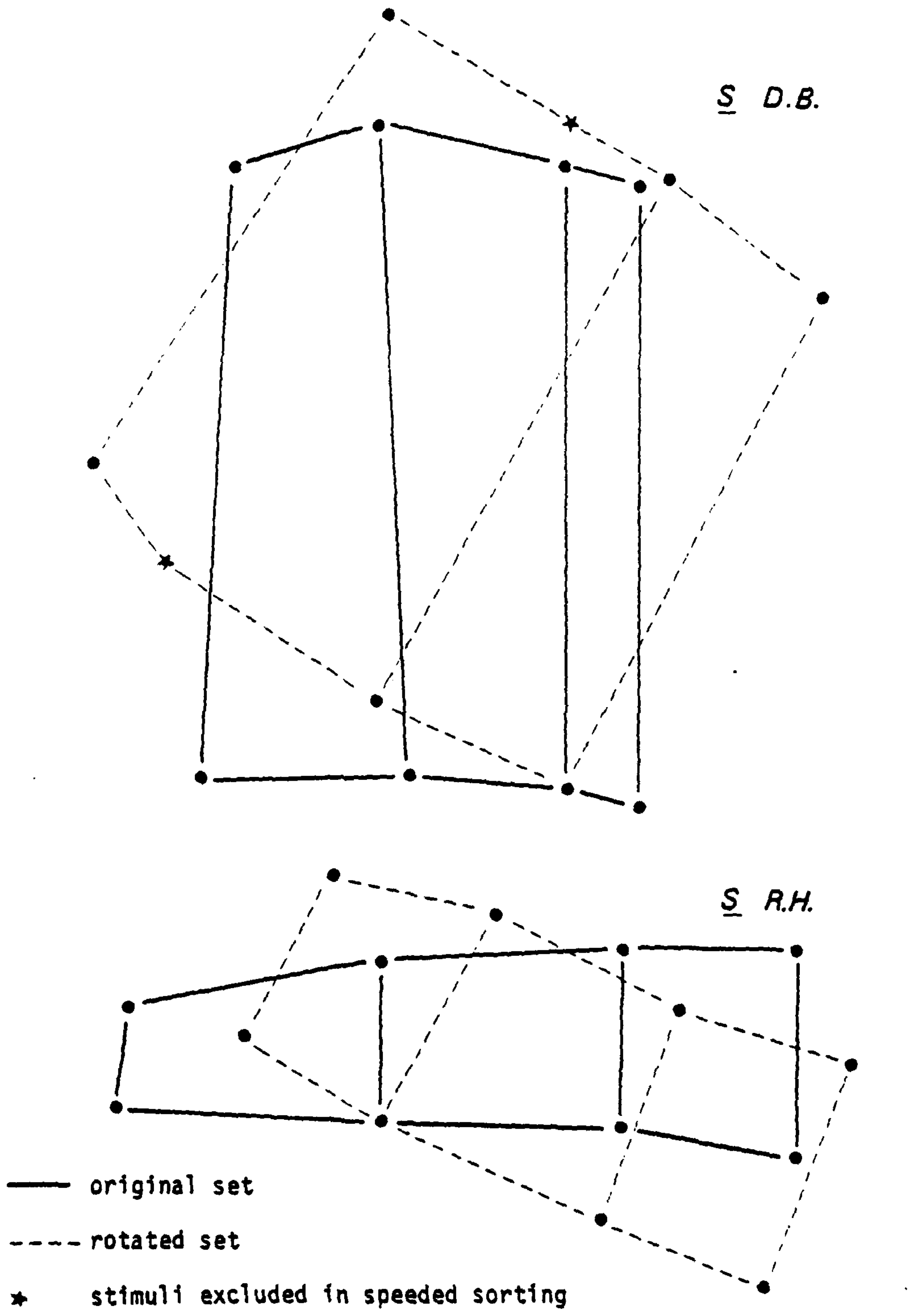


Figure 10. Multidimensional scaling configurations of lowest stress for subjects D.B. and R.H.: Experiment II.

figurations of minimum stress to the constrained configurations were small, it was concluded that the sets of stimuli were satisfactorily rectangular. Not all triangles appearing in the dissimilarity judgment task appeared in the speeded sorting tasks. Only those that formed rectangular configurations appeared. Those chosen are connected into rectangular groups in Figure 10. Solid lines connect stimuli in the "original set"; dashed lines connect those in the "rotated set". The labels "original" and "rotated" will be explained in the Procedure section.

3.1.3 Procedure

The general procedures for the dissimilarity judgment and speeded sorting tasks were described in the last chapter. From a subject's point of view, what were different were the triangles presented, the number of sessions of the two tasks, and the way some triangles were to be classified.

3.1.3.1 Dissimilarity judgements

The goal of the dissimilarity judgment task was to arrive at two sets of triangles with properties described in the last section. To achieve this, each subject was first presented with a set of 16 orthogonally varied triangles that produced roughly rectangular configurations. For subject D.B., this initial set was an orthogonal combination of 4 values each on R and α, with the ratio of R and the length of the base (B) kept constant. For subject R.H., the physical dimensions of an analogous set were H X R on the one hand, and α on the other, with B kept constant.

For each subject, eight stimuli that formed a column of three

adjacent, roughly rectangular sets were selected. The final set which was derived from these eight stimuli was designated the "original set". To these eight stimuli were added another eight, which were an estimate of the "rotated set". This estimated set was arrived at by assuming the initial orthogonal dimensions to be axes of the underlying psychological space. These estimated sets were presented to the respective subjects for dissimilarity judgments. Using the resultant configuration as a guideline, stimulus values for both the estimated original and rotated sets were adjusted by interpolation and extrapolation. The adjusted sets were then again presented for dissimilarity judgments. This cycle was repeated until satisfactory sets were obtained. For D.B., this process took a total of six actual sessions; for R.H., it took five. For neither of the subjects did the axes of the original or the rotated sets correspond to the initial orthogonally varied dimensions. However, on the basis of physical stimulus values for both subjects, the original set corresponded more closely than the rotated set to the original dimensions. (See Appendix G.)

3.1.3.2 Speeded sorting

Each subject sorted 4 sessions, each session lasting about 1 hour. In each session, the subject sorted 19 sets of triangles, some with 2, others with 4 triangles each. All triangles presented in a single session were from a single set -- either original or rotated. One subject did the sessions in the order original, rotated, rotated, original; the other subject in the order rotated, original, original, rotated. The 19 sorting sets in each orientation are of 5 task types: two orthogonal sorting -- one requiring stimuli on the same horizontal axis of the configuration (H) to be in one category (this will be

referred to as sorting by the horizontal axis); the other requiring those on the same vertical axis (V) to be in one category (this will be referred to as sorting by the vertical axis); two unidimensional sorting -- again one according to each axis; and one diagonal sorting. Each task type was performed on each of three rectangular sets of stimuli. The ordering of the 19 sets within a session was random.

3.2 Results and Discussion

Results were analyzed separately for each subject. This was because triangles presented to the subjects were of entirely different stimulus values, and the multidimensional scaling configurations were not comparable in either orientation or discriminability. There was no firm, rational common basis for averaging. To avoid averaging over non-comparable entities, results for each subject were analyzed separately.

Error rates for both subjects were low: 3% for D.B., and 4% for R.H. Correlations between the RT's of correct responses and errors were high: .85 for D.B., and .66 for R.H. ($\underline{p} < .01$). For ease of analysis, RT's for errors were included.

Analysis of variance was run in two steps, first across task types, then within individual task types, as in the last experiment. The factors for the first analysis were orientation (O), and task type (T); the factors for the second analysis for every task were orientation (O), stimulus set (G), stimulus (St), run (R), and trial (Tr). Analysis of variance tables are given in Appendix H.

The amounts of interference for sorting by each axis (H and V), and the mean sorting time for diagonal sorting are listed separately for each subject on Table 7.

Table 7

Interference and Diagonal sorting time for original and rotated sets for each subject

D.B.	Original Set	Rotated Set	Difference between sets
Interference (H) in msec	38±15	68±15	-30±22
Interference (V) in msec	60±16	103±16	-43±22
Diagonal sorting time in msec	650±33	598±33	52±47
R.H.			
Interference (H) in msec	70±17	73±17	-3±25
Interference (V) in msec	26±23	100±23	-74±32
Diagonal sorting time in msec	761±30	648±30	113±43

Note. Error margins given in this table are 95% confidence intervals.

For both subjects, results were in the pattern predicted by the compatibility theory with fixed dimensions. Both the original and the rotated set produced significant interference, but the amounts of interference were significantly different for the two orientations. Sorting time for the diagonal task was also significantly different for the two orientations, being faster for the orientation with more interference, as was expected in the case of fixed dimensions. Note also

that for both subjects, the original set produced less interference and slower diagonal sorting, confirming our expection that the original set corresponded more closely with psychological dimensions. That both sets produced interference suggests two possibilities. One is that although one set corresponded more closely with psychological dimensions, neither set corresponded closely enough for the within-class variability produced to be negligible. A second possibility not previously mentioned is that subjects were distracted. This explanation is not to be confused with that of failure to pay selective attention due to the "integrality" of stimuli. In that case, failure is due to the encoding structure, and hence is unavoidable. In the case of distraction, failure is due to process, which ought to be avoidable under the right conditions. Since there are results relevant to the issue of distraction in experiments in the next chapter, a discussion of it will be postponed until then. Before moving on to a consideration of discriminability as an explanation of the pattern of results obtained, it will be mentioned in passing that a similar pattern of results -- interference on sets of different orientations, but greater interference on one of the orientations -- was obtained with children on the dimensions size and shade (Smith & Kemler, 1978). As mentioned in the Introduction, Smith and Kemler proposed a "continuum of dimensional primacy".

Because stimulus sets of the two orientations for both of the subjects were not exact rigid rotations of each other -- they differed in discriminibility along the axes-- the possibility arises that dif-

ferences between amounts of interference produced by the two sets may be due to the artifact of differences in discriminability between sets of the two orientations, rather than due to the difference in orientation. In other words, the stimuli may not be dimensionally encoded.

To examine this possibility, the correlation between interference and the relative discriminability of the sets of stimuli was calculated. The correlation was - .45 for D.B. and - .43 for R.H. (p > .10). Though insignificant, both were negative, as predicted by the first model mentioned earlier. However, a closer examination of relative discriminability and interference, along with an assumption, shows that relative discriminability cannot account for the pattern of interference.

Comparing relative discriminability and interference between orientations for orthogonal sorting by each axis, two results were apparent.

1. For D.B., interference was higher for the rotated set for sorting by both axes. However, the relative discriminability for sorting by the vertical axis was higher for this set than for the original set-- the relative discriminabilities for this task for the original and the rotated sets were respectively .55 and .65. But the rotated set produced more interference. This is contrary to what would be predicted on the basis of relative discriminability: higher relative discriminability should lead to less interference. This result is sufficient to rule out relative discriminability as an explanation for greater interference for the rotated set. Thus, results for D.B.

showed that orientation affected performance.

2. For R.H., unfortunately, the discriminabilities of the two orientations were not such that a similar inference could be drawn. The mean relative discriminabilities for the original and rotated sets, for sorting by the horizontal axis were .78 and 1.22 respectively;while for sorting by the vertical axis, they were 1.42 & .83 respectively.In the task where relative discriminability was higher for the rotated set (sorting by the horizontal axis), interference was not significantly different for the two sets.

However, if we adopt for the moment the hypothesis that interference occurs in an amount inversely proportional to relative discriminability, we will arrive again at the conclusion that relative discriminability cannot account for the difference in interference between the original and the rotated sets. Comparing interference for the two orientations, we would expect on the basis of the above hypothesis that, for any one orientation, greater interference for sorting by one axis due to lower relative discriminability should be compensated by less interference of a similar magnitude for sorting by the other axis. This is because relative discriminability--defined as the ratio of the discriminability along the relevant and the irrelevant dimensions--for sorting by one axis is the reciprocal of relative discriminability for sorting by the other axis. Thus, advantage in sorting by one axis for any one orientation should be matched by disadvantage of a similar magnitude for that same orientation in sorting by the other axis. This prediction was not born out by the pattern of inter-

ference for R.H. While the greater relative discriminability in sorting by the horizontal axis for the rotated set produced no advantage at all (The rotated set produced on the average only 3±25 msec more interference), the reciprocally lower discriminability in sorting by the vertical axis for the same set produced a large disadvantage. (The rotated set produced an average of 74±32 msec more interference.)

Thus, while relative discriminability could be a factor influencing the amount of interference, it could not account for the larger amounts of interference obtained here for one orientation over the other.

In sum, orientation affected sorting performance. This suggests that the internal representation of triangles was dimensional, and that the dimensions were fixed. That in a "separable" domain interference occurred, and that it occurred in an amount inversely related to diagonal sorting time imply that neither interference, nor the inverse relationship between it and diagonal sorting time can be taken as criteria for defining "integrality". That rectangularity did not predict performance implies that it is not sufficient as a measure of compatibility. Orientation, at least, needs to be specified. That dimensions were fixed may appear contrary to the general observation that context affects perception. A possible resolution is that the context created by the orientation of rectangular sets was not one that redefined the psychological dimensions.

3.3 Conclusion

The results were not consistent with the hypothesis that the domain of triangles was encoded in a Euclidean space. They were consistent with the compatibility theory along with the hypothesis of fixed dimensions, according to which 1) the domain was represented dimensionally, in support of the result in Experiment I: Part one and 2) rectangularity was not sufficient as an indicator of compatibility. The compatibility theory and the hypothesis of fixed dimensions together explain the inverse relationship obtained between interference and diagonal sorting time, and degrees of integrality.

CHAPTER IV

EXPERIMENTS III AND IV:

TESTS OF THE NECESSITY OF RECTANGULARITY, AN EXPLANATION OF ASYMMETRIC INTEGRALITY AND AN ISSUE OF SELECTIVE ATTENTION

Both experiments in this chapter attempt to test whether rectangularity is necessary for separability. The concept of rectangularity is examined because it potentially provides a systematic definition of psychological (i.e., psychophysically compatible) dimensions. A definition of psychological dimensions independent of speeded classification performance is crucial to the viability of the compatibility theory. Both experiments in this chapter are based on the idea that separability need involve selective attention to only one dimension. Experiment III concerns a technical aspect of rectangularity, and at the same time provides an explanation of asymmetric integrality. Experiment IV concerns a substantive aspect of rectangularity.

Even though rectangularity is a plausible definition of psychological dimensions, rectangularity and the compatibility theory are independent concepts. In other words, the validity of rectangularity need not affect the validity of the compatibility theory. In addition, arguments and results concerning rectangularity apply not only to compatibility theory, but to general considerations regarding the defining properties of psychological dimensions. Two basic axioms

underlying rectangularity--interdimensional additivity and intra-dimensional subtractivity of overall similarity judgments-- have been proposed as defining properties for psychological dimensions in a series of papers (Beal, Krantz & Tversky, 1968; Krantz & Tversky,1975; Tversky and Krantz, 1970). Experiment IV is relevant to this proposition.

4.1 Experiment III

Previous literature on integrality and separability have invariably mentioned dimensions in pairs. This is probably because integrality and separability were thought to arise from ways in which physical dimensions combine with each other. Some combinations remain distinct, while others interact to form a new,integral psychological dimension. It is probably due to this mode of thinking that the Euclidean spatial model rather than the city block spatial model has been the point of focal interest.

The compatibility theory does not merely reverse the point of focal interest, it provides a different framework. According to this theory, some combinations of physical dimensions form new psychological dimensions(as in the old theory), but these psychological dimensions are separable. It is not the combination *per se*, but the incompatibility between the physical dimensions and these psychological dimensions which lead to phenomena associated with integrality . According to this theory then, the separability of single dimensions can be evaluated alone, without reference to any particular second dimension. The exception to this is when the second dimension redefines the psychological dimensions, in which case

a previously compatible dimension becomes incompatible. However, as noted in the last chapter, not all physical dimensions redefine the psychological dimensions. Within the context of a stable set of psychological dimensions, then, the compatibility of single dimensions can be evaluated independently of any particular second dimension.

This inherent feature of the compatibility theory of the separability of single dimensions provides a ready explanation of asymmetric integrality. The term asymmetric integrality has been applied to cases where one of two orthogonally varied dimensions produced interference whereas the other did not (Garner, 1974, referring to Day and Wood, 1972, and Wood, 1974), and also to cases where one of the dimensions produced greater interference than the other (Pomerantz & Sager, 1975). Without the concept of compatibility, asymmetry was quite inconsistent with Garner's models of a Euclidean space and a city-block space. There cannot be a space where one dimension is Euclidean and the other city-block. To explain the asymmetry, various strategies and levels of processing have been hypothesized (Garner, 1974; Pomerantz & Sager, 1975). Indeed, the very classification of asymmetry as a type of "integrality" is revealing of the framework. Within the alternative framework of compatibility theory, the phenomenon might be more naturally labelled "asymmetric separability." If one dimension is separable, i.e., compatible, and another is not, one dimension would produce interference while the other would not. The same basic idea that the separability of a dimension can be evaluated without particular reference to a second dimension applies to degrees of asymmetry, and to rectangularity.

Figure 11 shows a schematic scaling configuration of a set of stimuli that has no variability within each response class along dimension x. X, represented by the horizontal axis, is the relevant psychological dimension. Each dotted line represents the locus of points with the same value along x. It should be obvious from the figure that if sorting is to be performed according to value on dimension x, then any quadrilateral set formed by connecting the two dotted lines should show no interference, since stimuli of the same category are of the exact same value. Thus rectangularity requires more than is necessary to define any one psychological dimension. This suggests that what is necessary, but again not sufficient, is parallel lines in a multidimensional configuration of similarity judgments. Even this, however, will be questioned in Experiment IV.

There is no reason to expect two orthogonal dimensions picked by an experimenter to both be psychological. Mistaking rectangularity as a necessary defining property would mean unnecessarily ruling out psychological dimensions until we hit upon two that are both psychological. Indeed, this misunderstanding may cause a premature abandonment of the compatibility theory,because we corner ourselves into the embarrassing position of not being able to find any psychological dimensions for even the simplest of forms.

The purpose of this experiment is to test whether there is any difference in the amount of interference produced by two sets of stimuli with different irrelevant dimensions, or with different values along the same irrelevant dimension -- hence of different degrees of rectangularity -- but with the same values along the

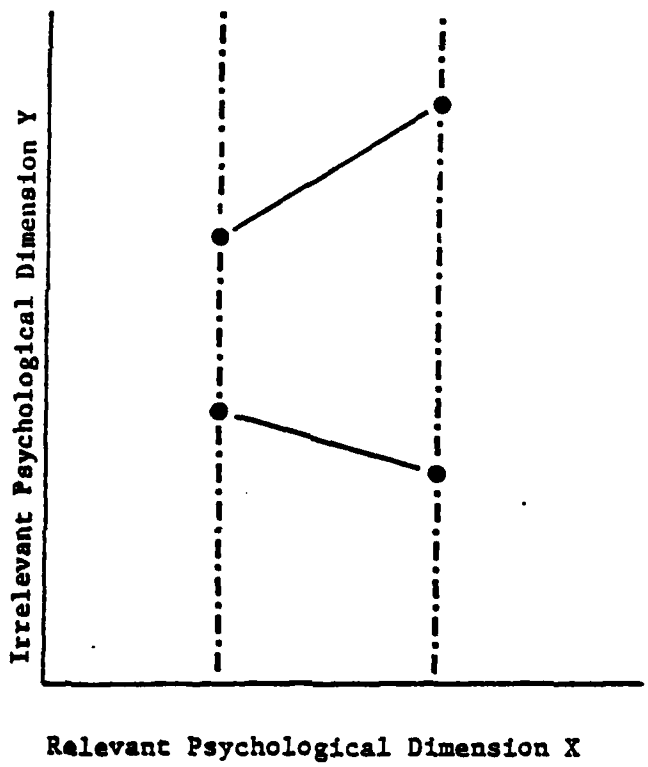


Figure 11. Non-rectangular set with no within-class variability along the relevant psychological dimension.

psychological dimension. This hypothetical psychological dimension was shape, as in Experiment I. Sometimes the relevant dimension was α(i.e., one compatible with the psycholoqical dimension); other times the relevant dimension was incompatible. In other words, the experiment tests whether the compatibility of a dimension (the relevant dimension) can be evaluated independently of any particular irrelevant dimension or values along the irrelevant dimension.

Since the shape and the interaction (defined as the ratio of the two diagonals of a quadrilateral set of stimuli, Somers, 1978) of a configuration change with changes in the irrelevant dimension, this experiment also tests whether the shape of the configuration (e.g. rectangularity) and interaction have any effect on the amount of interference when values along the psychological dimension are kept constant.

4.1.1 Method

Except for a difference in triangle values, the method in this experiment was exactly the same as that in Experiment I, including the subjects, the procedure, and the division into two parts. Accordingly, only a few differences will be mentioned here.

4.1.1.1 Stimuli in Part One

Four sets of triangles with four triangles in each set were constructed. Two of the sets were formed by othogonal combinations of α --a hypothetically compatible, relevant dimension for sorting--

and an irrelevant dimension. For one set, this irrelevant dimension was length of left side (L), for the other, it was length of right side (R). Since both sets had the same values on the relevant dimension, which was hypothetically compatible, neither set should show any interference. However, since the two sets had different irrelevant dimensions, their scaling configurations should have different shapes, in particular, different degrees of rectangularity. Such a pattern of results would therefore indicate that the separability of a dimension could be evaluated without reference to any particular second dimension, providing an explanation for asymmetric integrality. At the same time, such a pattern of results would imply that rectangularity is not necessary for defining separability.

The other two sets of triangles were also matched with each other on their α values, but had different configurations due to different values along the irrelevant dimension. Unlike the first two sets, these sets had with-class dimensional variability. The experimental set had H, a hypothetically incompatible dimension, as the relevant dimension. Stimulus values for all four sets are listed in Table 8. Compared to Experiment I, instead of having control sets with exactly the same values as the corresponding experimental sets on the psychological dimension α, but longer Euclidean distances, this experiment had control sets, also with exactly the same values as the corresponding experimental sets on α, but with less interaction. According to compatibility theory, there should be no difference in interference between experimental and control sets; but sets with a compatible relevant dimension should show no interference, while sets

with an incompatible relevant dimension should show interference. In other words, values along the irrelevant dimension (which affect the shape of the configuration) should not affect the compatibility of the relevant dimension.

4.1.1.2 Stimuli in Part Two As in part one, there were again two experimental sets and two control sets with less interaction. Both experimental sets were orthogonal combinations of L and R (L being the relevant dimension) but one set had greater within-class variability than the other. According to compatibility theory, sets with greater within-class variability should show greater interference, but experimental sets should show the same amount of interference as the control sets; that is, the shape of the configuration should not have any effect when values along the psychological dimension were kept constant.

Stimulus values are listed in Table 9.

4.1.2 Results and Discussion

Analyses paralleled those in Experiment I.

4.1.2.1.1 Part One: Dissimilarity Judgments

The configuration of lowest stress for subject S.L. is shown in Figure 12. As mentioned in Experiment I, stimuli from each part of the two experiments were grouped. These configurations were subsets of the entire set of 16 stimuli, the lowest stress for which was .04 for subject S.L. As can be seen from the figure, the sets differed in shape. Of the two that had α as the relevant dimension,

Table 8

Stimulus Values for Experiment III: Part One

Stimulus Set	Dimension		
	α		L
α by L	61		40
	39		40
	61		49
	39		49
	α		R
α by R	61		22
(control set for	39		22
by L)	61		25
	39		25
	α	H	R
H by R	39	14	22
	82	22	22
	34	14	25
	61	22	25
	α		R
control set for	39		25
H by R	82		22
	34		22
	61		25

Table 9

Stimulus Values for Experiment III: Part Two

Stimulus Set	Dimension α	L	R
set a: small within-class variability	70	36	22
	77	36	23
	43	41	22
	53	41	23
set b: large within-class variability	70	36	22
	83	36	24
	25	43	22
	53	43	24
control set for set a	70		22
	77		23
	43		23
	53		22
control set for set b	70		22
	83		24
	25		24
	53		22

one set was more rectangular than the other. The interactions of the two experimental sets were 1.5 (α by L), 1.4 (H by R), and the interactions of the two control sets were both 1.2. The experimental sets had higher interaction.

The scaling solution for the second subject was, as mentioned in Experiment I, degenerate. However, using as estimates the mean pairwise dissimilarity judgments for stimuli that would have been diagonals were the scaling solution not degenerate, the interactions of the two experimental sets were 1.2 for both experimental sets, 1.0 for the α by R set, and 1.1 for the other control set. Interaction was thus slightly higher for the experimental sets.

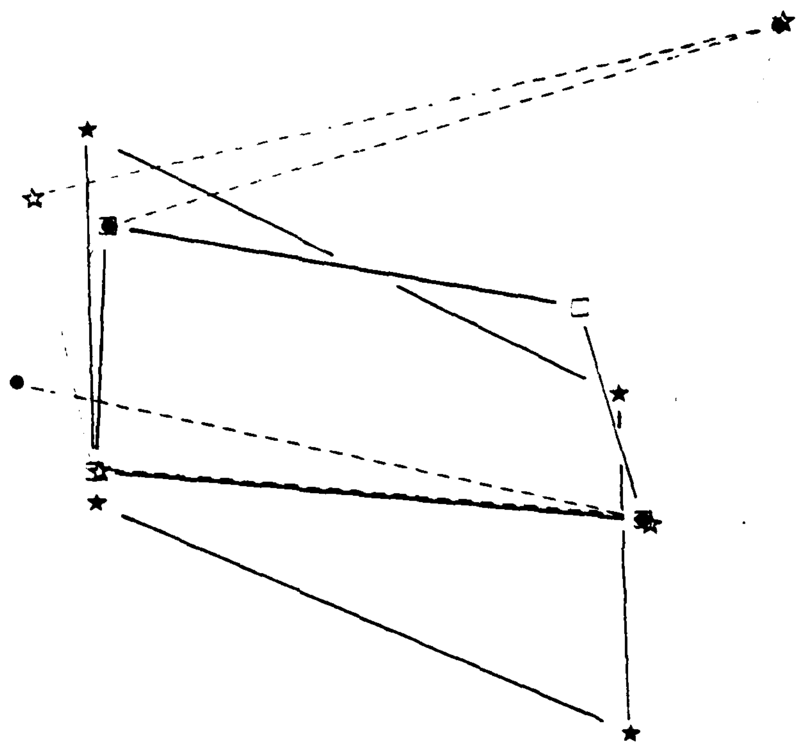
4.1.2.1.2 Part One: Speeded sorting performance

Mean error rates were low: 1% for subject S.L. and 4% for subject C.H. Correlations between RT's for correct responses and errors were high: .7 for S.L. and .8 for C.H., $p < .05$. For ease of analysis, RT's for errors were included in the analysis.

Analysis of variance tables are given in Appendix I. As before, unless otherwise stated, error margins given below are 95% confidence intervals.

Sets with high interaction (experimental) produced 44±10 msec of interference; sets with low interaction (control) produced 37±10 msec of interference. As predicted by the compatibility theory, this difference, 7±13 msec, was not significant.

Sets with H -- a hypothetically incompatible dimension -- as the relevant dimension produced 48±21 msec of interference. Sets



★——★ α by L: hi interaction

□——□ α by R: lo interaction (control)

●---● H by R: hi interaction

☆---☆ control group for H by R set: lo interaction

Figure 12. Multidimensional scaling configuration of lowest stress for subject S.L.: Experiment III (Part one)

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A PSYCHOPHYSICAL APPROACH TO FORM PERCEPTION: INCOMPATIBILITY A--ETC(U)
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with α -- a hypothetically compatible dimension -- as the relevant dimension produced 35 ± 21 msec of interference. The difference, 13 ± 30 msec, though in the direction expected, was not significant. That sets with a compatible relevant dimension should produce interference was somewhat unexpected. However, given the phenomenological appeal of geometrically similar triangles being of the same shape, and given the evidence from Experiment II that triangles are dimensionally encoded, and the evidence from Experiment I (part one) that α is a compatible dimension, it is suggested that the interference obtained in this case is due to a failure -- rather than an impossibility -- of selective attention (due to failure in process rather than due to inherent structure). A fuller discussion of this problem will be postponed until the end of this chapter.

The statistical interaction of compatibility x interaction was significant. This is quite uninterpretable at the moment. The number of subjects was clearly small and the variation across the two subjects was considerable. Results of individual subjects are listed in Table 10. The variation could not at the moment be interpreted as anything other than noise. This experiment is being replicated. Until a reliable pattern appears, it seems futile to make any attempt at interpreting results that are not consistent with any theory.

Table 10

Experiment III: Part One: Interference (in msec) for Individual Subjects Under Various Conditions

Subject	Condition	
	compatible relevant dimension (α)	incompatible relevant dimension (H)
S.L.	36	33
C.H.	34	61
	high interaction (experimental)	low interaction (control)
S.L.	41	29
C.H.	48	46

Note: The 95% Scheffe simultaneous confidence interval for controls listed in this table is ± 20 msec.

4.1.2.2.1 Part Two: Dissimilarity Judgments

As mentioned in Experiment I (part two), the scaling solution for subject S.L. was degenerate unless constrained. The stress for the constrained solution was quite low (.05), indicating that the fit was reasonable good. The constrained solution for this experiment is shown on Figure 13. As can be seen, the sets differed in shape. The interactions of the two experimental sets were 1.7 and 2.8, and those for the control sets were 1.2 and 1.8. Each of the experimental sets had a higher interaction than its control set.

For subject C.H., using the same estimates as in part one, the interactions for the experimental sets were 1.3 and 2.1, and those for the control sets were 1.1 and 1.7. Again, each of the experimental sets had a higher interaction than its control set.

4.1.2.2.2 Part Two: Speeded Sorting Performance

Mean error rates were low: 1% for S.L. and 3% for C.H. As correlations between RT's for correct responses and errors were highly significant, for ease of analysis, RT's for errors were included.

Analysis of variance tables are given in Appendix J.

Sets with high interaction (experimental) produced 70 ± 12 msec of interference. Sets with low interaction (control) produced 96 ± 12 msec of interference. The difference of -26 ± 17 msec was significant. This effect was opposite in direction to that obtained in part one, and also opposite to that predicted by Somers(1978).

Sets with small within-class variability produced 70 ± 29 msec of interference. Sets with large within-class variability produced

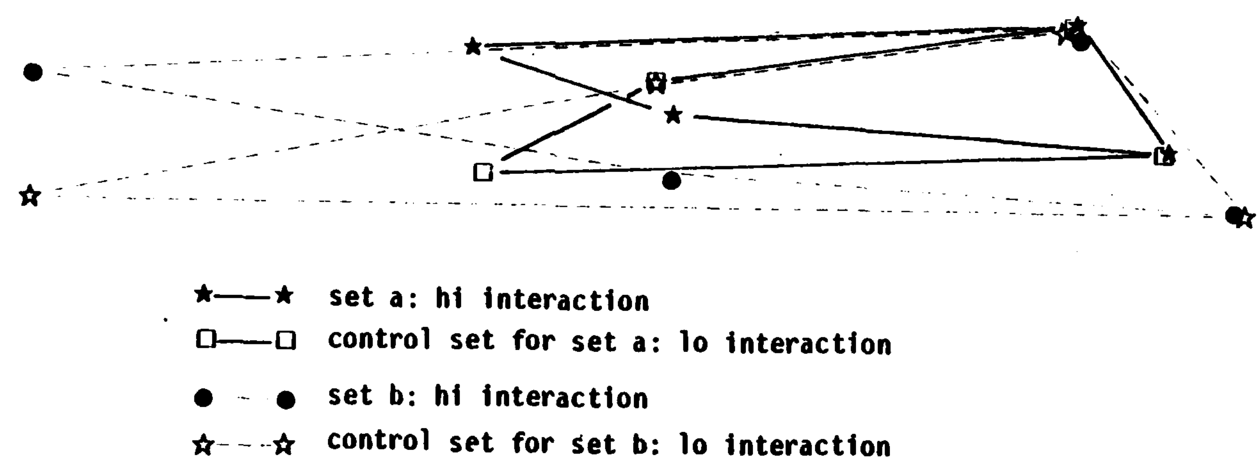

Figure 13. Constrained multidimensional scaling configuration for subject S.L.: Experiment III (part two).

97±29 msec of interference. The difference, though in the direction expected, was insignificant (27±41 msec).

The statistical interaction between Dimensional within-class variability and Interaction (D X I) was insignificant ($F = .29$, $p > .10$).

Results of individual subjects are listed in Table 11. They reflect a similar pattern as in the averaged results.

Table 11

Experiment III: Part Two: Interference (in msec) for Individual Subjects Under Various Conditions

Subject	Condition	
	small within-class variability	large within-class variability
S.L.	76	81
C.H.	65	113
	high interaction (experimental)	low interaction (control)
S.L.	61	94
C.H.	79	98

Note: The 95% Scheffe simultaneous confidence interval for contrasts listed in this table is ±24 msec.

Dimensional within-class variability had a consistent, though statistically insignificant, effect on the amount of interference obtained in the two parts of this experiment: the greater the variability, the greater the interference. On the other hand,

the shape of the configuration, or the amount of interaction, did not have any consistent effect on interference. Its effect went in opposite directions in the two parts, and in the part where it was significant, it was in opposite direction to that predicted by Somers (1978). The statistical interaction between dimensional within-class variability and interaction was also inconsistent across the two parts.

If the compatibility of a dimension could be evaluated without reference to any particular second dimension, then the possibility of asymmetric separability follows directly, and the lack of a need for rectangularity follows directly. However, given the noisiness of the data, it could only be said that it seems to be the case that the compatibility of a dimension is not consistently affected by variation on the irrelevant dimension.

4.2 Experiment IV

Rectangularity was questioned in the last experiment, under the assumption that the independence of overall similarity judgments defines the independence of psychological dimensions. Under this assumption, while rectangularity is not necessary to indicate the independence of any one dimension, non-rectangularity does necessarily indicate the incompatibility of at least one of the physical dimensions. Here it will be argued that the nature of the similarity judgment task itself requires more than is necessary to define the independence of psychological dimensions, so that non-rectangularity need not imply the incompatibility of even

one dimension.

Given a certain psychological structure, different patterns of performance can result due to differences in process. The characteristics of the underlying structure may not always be manifest due to the intervening processes. This may be the case with overall similarity judgments. To define a psychological dimension, it seems sufficient to require only that one be able to pay selective attention to that one dimension independently of variation along other dimensions. Thus although two or more dimensions must be varied in order to observe the effect of an irrelevant dimension (or dimensions) on the relevant dimension, the subject need be required to pay attention to only one. However, overall similarity judgments, where two or more dimensions are varied, require the subject to either divide attention simultaneously over two or more dimensions or to attend sequentially to two or more dimensions; in addition, some rule must be used to combine the judgments on each dimension. It follows that independence of overall similarity judgments requires that the independence in the underlying structure remain intact and manifest after the processing. This may not be the case for several reasons.

First, the combination rule may obscure the underlying independence of dimensions. Second, subjects may encode the stimuli in more psychological dimensions than there are dimensions varied physically at any one time. It is likely (Stevens & Davis, 1938) that subjects might be equipped to compute an indefinite number of functions of the physical variables, and that the number of psychological attributes

need not be the same as the number of physical variables. If so, then performance based on divided attention or sequential selective attention of an "overall" nature may reflect more psychological dimensions than the number of dimensions varied physically. Thus, even though each of the physical dimensions could potentially be independently attended to one at a time (i.e., each is psychophysically compatible),"overall" similarity judgments of such stimuli need not be independent with regard to the physical variables manipulated. In other words, lack of independence in overall similarity judgments need not imply the lack of psychological independence of any of the physical variables. Lack of independence in overall similarity judgments was shown in this experiment by the non-rectangularity of scaling configurations.

Note that when a manipulated dimension is compatible, an orthogonal sorting task based on this dimension requires selective attention to only one dimension.

The purpose of this experiment is to see whether psychological dimensions yield independence in overall dissimilarity judgments. The rationale is simple: choose dimensions that have phenomenological appeal as being psychophysically compatible, provide converging evidence that these are indeed compatible by performance on orthogonal sorting, and obtain dissimilarity judgments on the set of stimuli. Independence of overall dissimilarity judgments was operationally defined in two ways: the increase in stress from a configuration of lowest stress to one constrained to be rectangular, and interaction (the ratio of diagonals; Somers, 1978).

4.2.1 Method

4.2.1.1 Subjects. The subjects were three paid undergraduate students at the University of Michigan. Their ages were 18, 20 and 21. All had normal vision. Two of them had been subjects in Experiment II.

4.2.1.2 Stimuli. The stimuli, common for all three subjects, were a set of 16 triangles formed by the orthogonal combination of 4 values on each of two dimensions: α and R, with R/B kept constant. The set is shown on Figure 14. It should be evident that triangles in each of the columns are identical in shape, and that each of the columns differ from each other by shape. Similarly -- though perhaps with less certainty -- it should be evident that triangles in each of the rows are of the same size, and that each of the rows differ from each other by size.

4.2.1.3 Procedure and Design. A within-subject design was used. Two tasks were administered: dissimilarity judgments and speeded sorting. Each subject completed two sessions of about 50 minutes each of dissimilarity judgments. There were two types of sorting: orthogonal and unidimensional. Each type of sorting was done according to each of the two dimensions: α and R. For each dimension, three levels of discriminability -- high, medium, and low -- along the relevant dimension were varied independently with three levels of discriminability along the irrelevant dimension. This variation was included to systematically examine the effect of discriminability along the relevant and irrelevant dimensions. A lack of a discriminability ef-

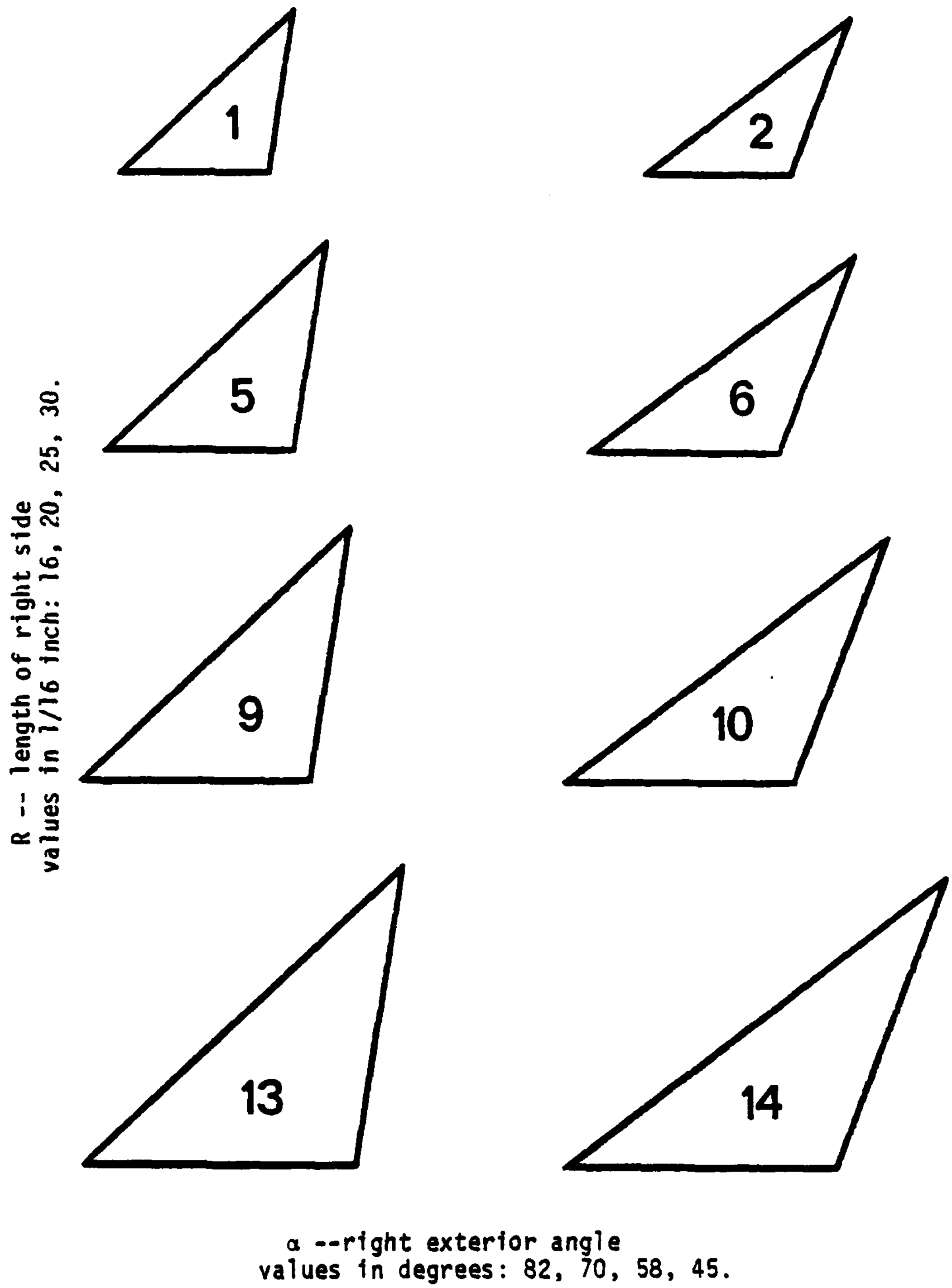

Figure 14. Experiment IV: triangles in R by α set.

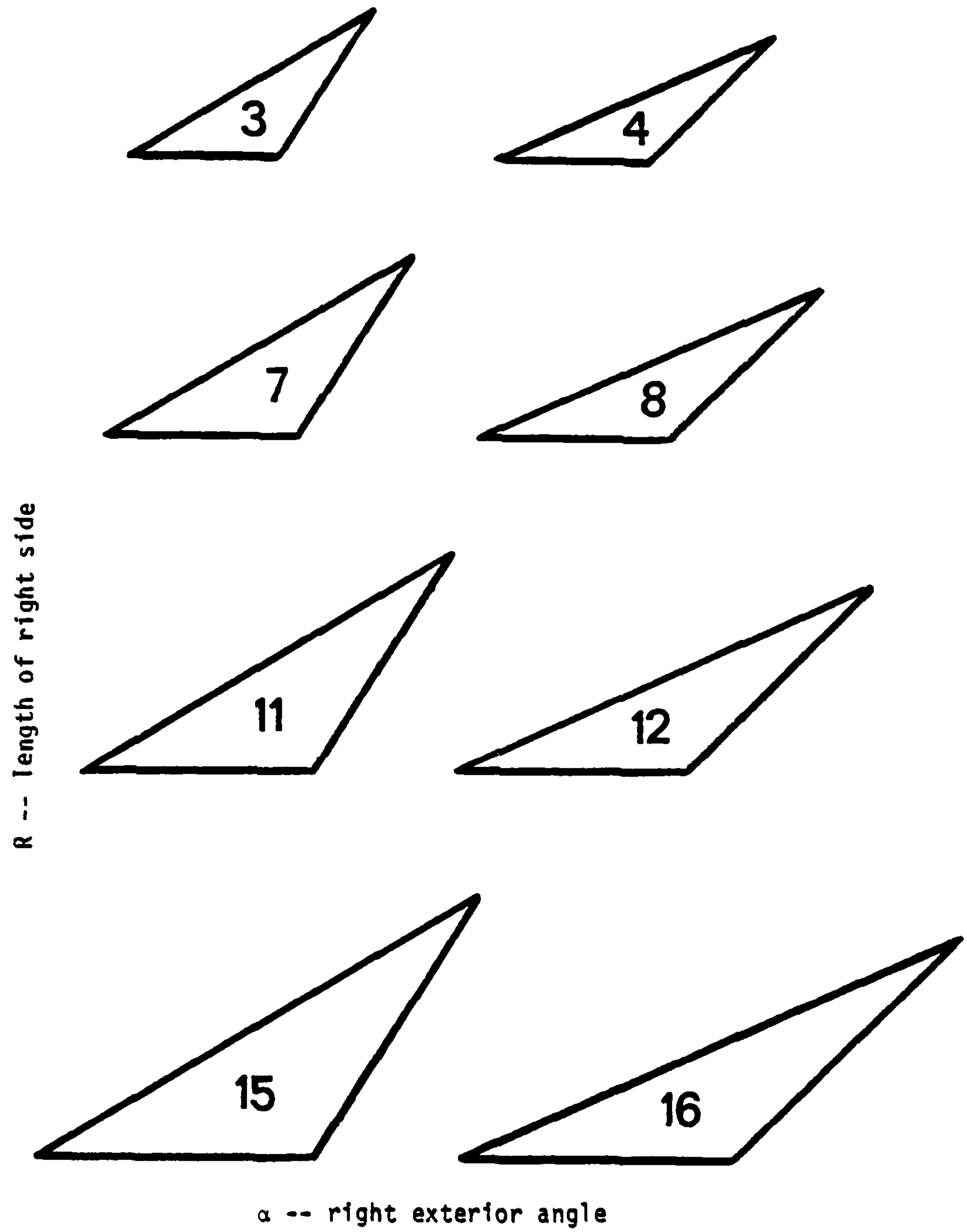

Figure 14 (continued). Experiment IV: triangles in R by α set.

fect of the irrelevant dimension would provide converging evidence that the relevant dimension was separable. The values of discriminability remained constant while the designation of relevance switched. As mentioned in the preceding section, there were 4 stimulus values on each dimension. For both dimensions, low discriminability meant that stimuli sorted were of adjacent stimulus values -- there were 3 such instances. High discriminability meant that stimuli sorted were of the two extremes of the four stimulus values -- there was one such instance. And medium discriminability, needless to say, fell in between -- there were two such instances.

Each block consisted of 10 stimulus sets of the same "relevant" discriminability: 6 orthogonal sets varying in 3 levels of "irrelevant" discriminability, and four unidimensional sets used as their baseline for calculating the amount of interference. The ordering of tasks within a block was random.

There were a total of 12 blocks: 6 blocks along each dimension -- 3 of low relevant discriminability, 2 of medium, 1 of high. Blocks of each dimension alternated. Within each dimension, the ordering of the blocks was random. There was one run of each block.

In addition to dissimilarity judgments and speeded sorting, subjects were asked at the beginning of the speeded sorting task to identify the two varying dimensions.

<u>4.2.2.1 Results: dissimilarity judgments</u>

Dissimilarity judgments of the α by R set by each of the subjects yielded multidimensional scaling configurations of minimum stress shown in Figure 15. The minimum stresses for D.B., R.H., and S.S.

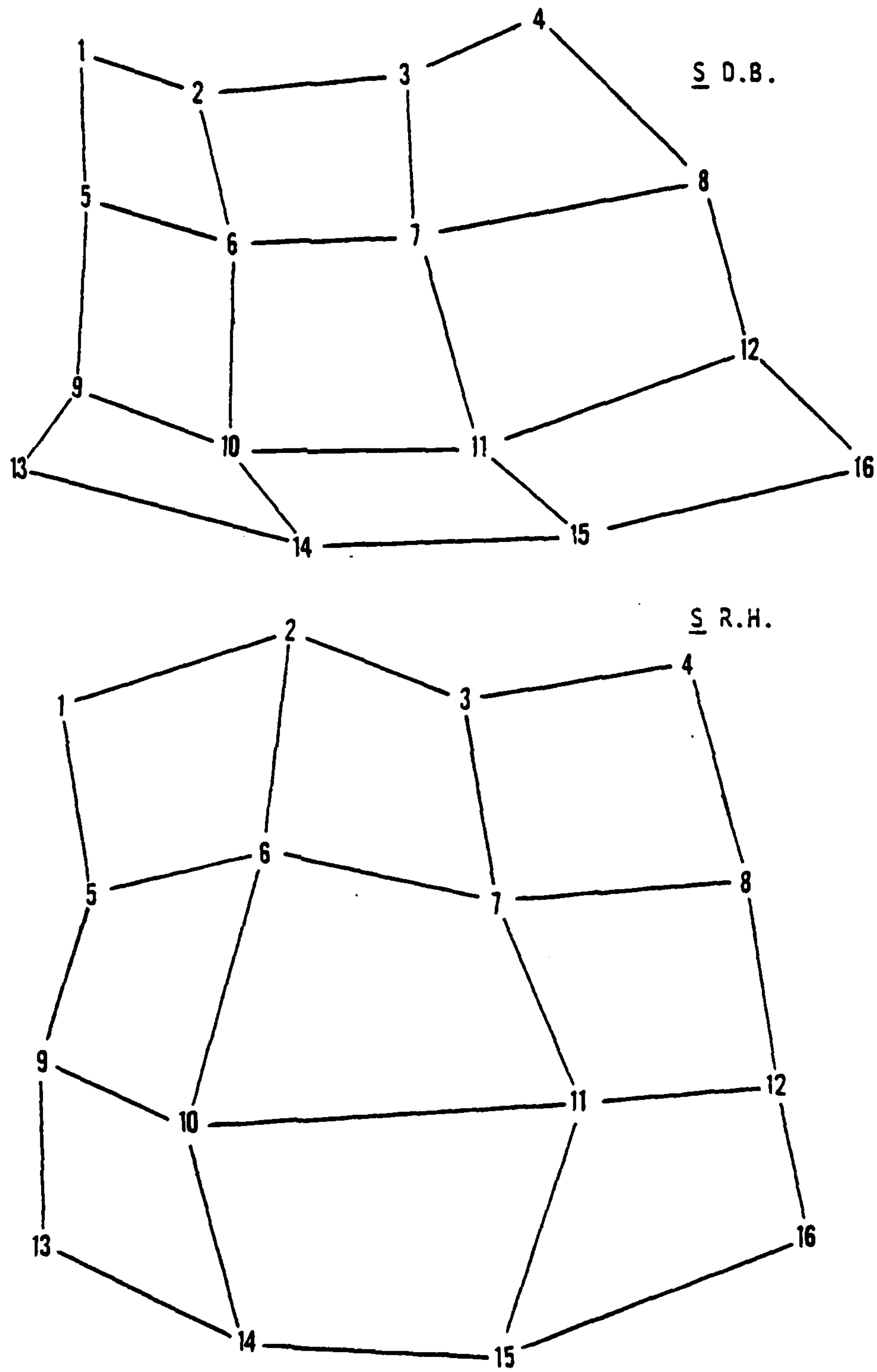

Figure 15. Experiment IV: multidimensional scaling configuration of lowest stress of R by α set for subjects D.B., R.H., & S.S. Numbers correspond to labels on triangles in Figure 12.

Figure 15 (continued). Experiment IV: multidimensional scaling configuration of lowest stress of R by α set for individual subjects.

were respectively, .10, .08, and .11. When these configurations were constrained to be strictly rectangular, the stresses were respectively .15, .11, and .19. These "constrained" stresses were high, and the increases from the minimum were considerable, particularly for D.B. and S.S. The configurations will therefore be considered non-rectangular.

For the three subjects, these solutions were computed from the mean of 9, 10, and 15 dissimilarity judgments of each stimulus pair, respectively.

Subjects promptly identified the dimensions as "size" and "shape" or "angle."

4.2.2.2 Results of speeded sorting

Error rates for speeded sorting were low: 3% for D.B. and R.H., 2% for S.S. Correlations between RT's for correct responses and errors were significant: they were .5, .6, and .5 for D.B., R.H., and S.S. respectively, $p < .01$. For ease of analysis, RT's for errors were included.

Analyses paralleled those in the preceding experiments. As before, they were carried out in two steps, across tasks and within individual tasks. The factors for the first step were attribute (A), discriminability along the relevant dimension (D), and task type (T). Task type here includes unidimensional and three orthogonal tasks of different discriminabilities along the irrelevant dimension. Orthogonal tasks of different discriminabilities along the irrelevant dimension were included in task type because, due to an unequal number of stimulus sets for each discriminability level, the tasks needed to

be analyzed individually. For individual task types, the factors were A, D, stimulus set (S), stimulus (St), and trial (Tr). A separate set of analyses was run for each subject. The analysis of variance tables for each subject are presented in Appendix K.

The mean RT's for each task type for each dimension for each subject are listed in Table 12.

Table 12

Mean RT's for Each Task Type for Each Subject for Each Dimension

RT to sort by α in msec

Subject / Task	D.B.	R.H.	S.S.
unidimensional	366±4	377± 4	378± 4
lo irrelevant	386± 6	390± 4	401± 5
med irrelevant	400± 8	419± 6	427± 7
hi irrelevant	423± 10	433± 10	449± 11

RT to sort by R in msec

Subject / Task	D.B.	R.H.	S.S.
unidimensional	403± 4	378± 4	387± 4
lo irrelevant	427± 6	383± 4	402± 5
med irrelevant	458± 8	412± 6	417± 7
hi irrelevant	443± 10	445± 10	461± 11

Note. Error margins given are 95% confidence intervals.

Correlations were calculated for each dimension between the mean amount of interference for each stimulus set,on the one hand, and the interaction of each stimulus set, and discriminabilities along the relevant and irrelevant dimensions,on the other. The correlations for each subject for each dimension are listed in Table 13.

Table 13

Correlations with Interference

Dimension	α			R		
Subject	D.B.	R.H.	S.S.	D.B.	R.H.	S.S.
Relevant discrim. (R)	-.45	-.22	-.38	-.51	-.38	-.52
Irrelevant discrim. (I)	.34	.54	.44	.29	.62	.29
Relative discrim. (R/I)	-.44	-.42	-.42	-.59	-.66	-.31
Interaction	-.27	.14	-.56	.31	.14	.54

Note: The correlation at .05 significance level for the above terms is $\pm .33$.

As can be seen, the discriminabilities along both the relevant and irrelevant dimensions were nearly all significantly correlated with interference, whereas interaction was either not significantly correlated or had no consistent effect. The high positive and negative correlations between interaction and interference for subject S.S. was likely due to the high correlation between interaction and relevant discriminability for this subject.

4.2.3 Discussion

Speeded sorting did not provide the expected converging evidence that α and R were psychologically independent. Without this confirmation, interpretation of the results is conditional. It seems that we would not want to conclude from the results obtained that rectangularity is a necessary property of psychological dimensions, for there is a possibility that interference was due, not to psychophysical incompatibility, but rather to a failure in selective attention.

Under the assumption that R and α are compatible dimensions, it was originally argued that there should be no interference or at least that discriminability of the irrelevant dimension should have no effect on the amount of interference. However, the *post hoc* hypothesis of failure of selective attention -- or distraction -- leaves the results not inconsistent with the compatibility theory, and with the assumption that R and α are compatible dimensions. Of course, if distraction were to consistently occur for some hypothetically compatible dimensions but not for others under similar conditions, some difference in structure might have to be hypothesized for the two types of dimensions.

Given the evidence from Experiments I and II that triangles are encoded dimensionally, and given the procedure in this experiment, the *post hoc* hypothesis of distraction is highly plausible. Each subject was required to sort according to both dimensions, with blocks of

each dimension alternating. This procedure could easily have led to confusion and consequent distraction. Moreover, extensive data was collected on each subject. Although this method has its advantages, the monotony involved was likely to cause distraction. It was an oversight that the subjects from Experiment II were asked to participate in this experiment. Although this provides a firmer basis for generalization across experiments, this also was likely to cause distraction. Since subjects uniformly remained polite while outside the experimental booth, it was not realized until too late that the task was probably atrociously boring.

The experiment is being replicated with a between-subject design with only one stimulus set under each condition.

It was mentioned in Experiment II that Smith and Kemler (1978) found interference on sets of different orientations, but greater interference for children on one of the orientations for the dimensions size and shade. A "continuum of dimensional primacy" in the developmental process was postulated. It seems that distraction with separable dimensions is a possible alternative explanation for their results.

It was mentioned in the Introduction that the high correlation between interference and relative discriminability obtained in Somers (1978) could be interpreted as a sign of Garnerian integrality. Here, it is argued that the correlation between the same variables could be interpreted as distraction. The contradiction is only apparent, for the following reason.

At the stage of investigation in Somers (1978), evidence for a separable domain was weak. The stimulus dimensions used did not have phenomenological appeal as psychological dimensions, there was as yet no demonstration that the orientation of a configuration had a definite effect on sorting performance, and the absence of interference for compatible dimensions was not clearly demonstrated. The stimulus structure was ambiguous: it could be integral; dimensional but incompatible (for example, with the axes of the rectangular sets rotated at an angle to the psychological dimensions); or dimensional and compatible. Indeed, along with different accompanying processes, all three structures could predict a correlation between interference and relative discriminability. Since the structure was ambiguous, the nature of the task was ambiguous, and the process must also be ambiguous.

In sum, the presence and pattern of interference is not inconsistent with compatibility theory and with the assumption that α and R are psychophysically compatible dimensions. Since the scaling configurations were non-rectangular, it may be tentatively concluded that rectangularity does not seem to be a necessary property of psychological dimensions.

It seems that the variability of the scaling configurations across subjects itself speaks against the reliability of overall dissimilarity judgments as a basis for the definition of psychological dimensions.

CHAPTER V

GENERAL DISCUSSION AND SUMMARY

The pervasiveness of interference in the experiments in this study warrants consideration.

A non-exhaustive review of the literature on integrality reveals that in all except one case (Shepard, 1964), absence of interference have been obtained for dimensions which are from different stimulus domains, such as color and size, or are in different locations. This suggests that distraction may be readily avoidable only for dimensions from different domains. (The case of dimensions in different locations is too trivial to be interesting.) The hypothesis that distraction is a cause of interference is independent of the distinction drawn between integral and separable dimensions. Distraction and integrality are conceptually different sources of interference. Interference from distraction arises from a failure in process, while interference from integrality arises from inherent structure. Thus, interference due to distraction is potentially avoidable under favorable conditions, but interference due to integrality is theoretically unavoidable.

Indeed, the concept of distraction assumes separability of representation. Only when representations are not fused and unitary does it make sense to talk of distraction of one by another. Distraction could potentially occur between separable dimensions

within or across domains, or between integral dimensions from different domains. If domain is a factor determining the distractability of dimensions, then there are at least two types of representation, one at the level of domain, the other at the level of dimensions.

The idea of domain may at first appear obvious -- for instance, pitch and color clearly belong to separate domains -- and therefore uninteresting. On closer inspection, however, it is not always so obvious whether or not two dimensions belong to different domains. Size and lightness, for instance, may appear to belong to different domains and have no interaction with each other. But they in fact interact. Objects appear bigger if they are lighter in shade. In a different manner, it is not clear whether size and shape constitute two separate domains, or the same domain of form.

5.2 Types of Representation

The concepts of distraction, domain , integrality, separability, and compatibility in combination create a number of plausible models of representation. The various possibilities are sketched on a chart (see Figure 16).

The chart may be summarized by several questions. One is whether there are separate domains between which there is little or no distraction and within which there often is considerable distraction. Another is whether below the level of domains, there are two types of representations (separable and integral), or only one type, and if so, which one. A further question is, within the separable type, whether or not compatibility has an effect.

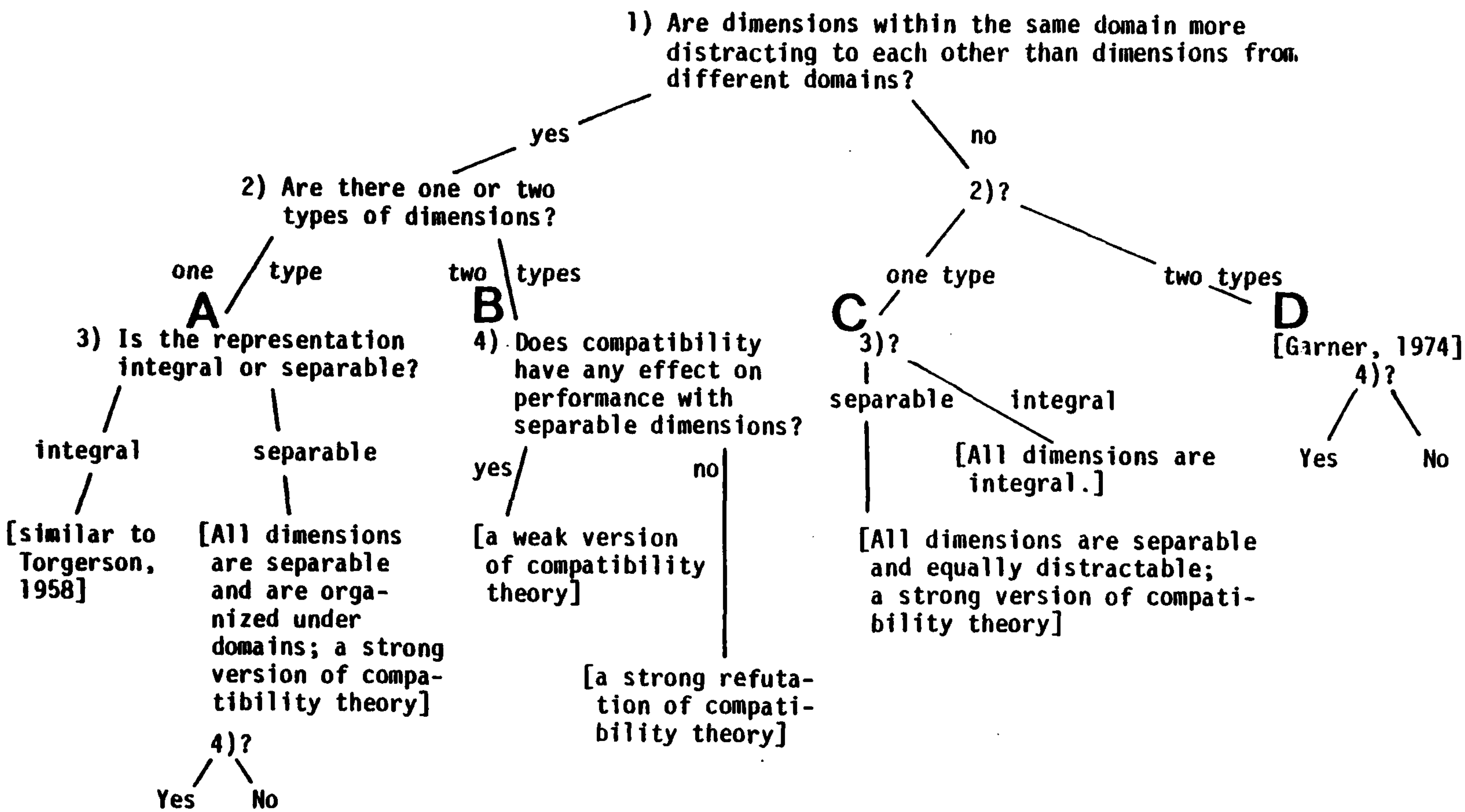

Figure 16. Compatibility theory in the context of types of representation. When questions are repeated, they are represented by their numbers.

Three of the four possibilities listed from A to D on the chart will be briefly discussed in turn. The fourth one, D, may be regarded as the original position of Garner (1974), according to which there are two types of internal representations, integral and separable.

A) Domain is important in determining distractability, and below the level of domain, there is but one type of representation.

This representation may be integral. In this case, encoding is very similar to Torgerson's (1958) concept. There are "attributes" which are separable, e.g. color and form. Within each attribute, dimensions are integral. For instance, hue and saturation within the attribute of color, and perhaps size and shape within the attribute of form. Torgerson's "attribute" is equivalent to the concept of "domain" introduced here.

Alternatively, this one representation below the level of domain may be separable, i.e., dimensional. In this case, although there are two types of representation, just as Garner postulated, the structures of encoding are quite different from those hypothesized by Garner. Here, all stimuli have a dimensional encoding, with the dimensions organized under different domains. Interference is caused by a possible combination of psychophysical compatibility and distraction. When conditions for concentration of attention are favorable and when the psychophysical mapping is compatible, interference should be avoidable.

B) Domain is important in determining distractability and below the level of domain, there are two types of representation, both integral and separable. There are then, a total of at least three

types of representation. Within separable dimensions, we may or may not get interference due to incompatibility.

The compatibility theory has so far been presented mostly in its strong version. There is a weak version of it which says that within the present model of three types of representation, interference can occur as a result of incompatibility. The possibility of interference due to integrality is not denied. However, the presence of interference due to incompatibility implies that interference cannot be taken as a criterion for integrality. Moreover, as noted earlier, since the whole pattern of results used by Garner to define integrality can result from incompatibility, the pattern itself cannot be taken as a criterion for integrality. That is to say, the consequence of accepting the effect of incompatibility, at the very least, is a thorough operational redefinition of integrality. In the next section, two related, new definitions will be proposed.

C) Domain does not affect distractability, and below the level of domain, there is but one type of representation. This representation may be integral, or separable. Since there is much evidence against the possibility that everything is integrally encoded, it will not be discussed. The alternative is that everything is encoded in dimensions. In other words, all results associated with integrality are due to incompatibility. This is the strongest statement that can be made about incompatibility. It denies the existence of Garnerian integrality. While it is virtually impossible to demonstrate the non-existence of something, if it is the case that everything explained by integrality can be explained by incompatibility, then it is more parsimonious to leave out the extra, and complex, concept of integrality.

Although it is virtually impossible to show the non-existence of integral dimensions, there is some as yet ambiguous evidence supporting the hypothesis. Kemler and Smith (1979) found that subjects in general have a tendency to use dimensional relations in a concept learning task, even for the exemplarily integral dimensions of brightness and saturation. They also found that whereas subjects consistently used a dimensional rule for separable stimuli, they tended to be inconsistent in the rule -- sometimes based on physically defined dimensions, other times based on similarity relations -- they applied for integral stimuli, and that the verbal rules they stated tended to be hedged or confused for such stimuli. These characteristics, puzzling when interpreted in terms of Garner's concept of integrality, follow quite naturally from compatibility theory. Integral stimuli are specified by incompatible dimensions. Rules defined according to such dimensions will therefore appear ill-defined to the subject.

However, support for the hypothesis that there are no integral dimensions is as yet ambiguous. There is also evidence that the orientation of a configuration did not affect sorting performance for brightness and saturation -- the same pair of dimensions mentioned above (Smith and Kemler, 1978). In addition, in the same study, the verbal reports of subjects on integral and separable stimuli seem convincingly distinct. However, although the authors concluded that orientation had no effect, some stimulus sets in their results were reported to be sorted significantly faster for sets of one orientation than for those of another.

5.2 New Criteria for Distinguishing Separable and Integral Dimensions

Two new criteria for distinguishing separable and integral dimensions will be proposed here. They follow directly from Experiments I and II and should by now be quite obvious.

First, the separability of a dimension may be tested by the effect of within-class distance (i.e., variability) along this dimension, with within-class Euclidean distance and between-class minimum dimensional distance controlled, as in Experiment I. Referring to Figure 17, if X is a psychophysically compatible dimension, under conditions favorable for selective attention, set A should show no interference, and set B should show some interference. If dimensions X and Y are integral in Garner's sense, both sets should show interference, and set B should show less interference (or at least no more interference), since it has greater between-class variability.

Second, the separability of a dimension may also be tested by observing the effect on interference in orthogonal sorting or diagonal sorting of the orientation of sets of stimuli with a fixed -- though not necessarily rectangular -- configuration. Using sets with a fixed configuration ensures that within- and between-class variabilities are controlled. Integral dimensions should not be affected by orientation; separable dimensions should.

These criteria are proposed as replacements for Garner's (1974) converging operations, rather than for rectangularity. Overall similarity judgments are used in these tests not to define psychological dimensions but to evaluate integrality as an explanation.

On the basis of arguments in the last chapter, it is suggested that a criterion in place of rectangularity should involve selective

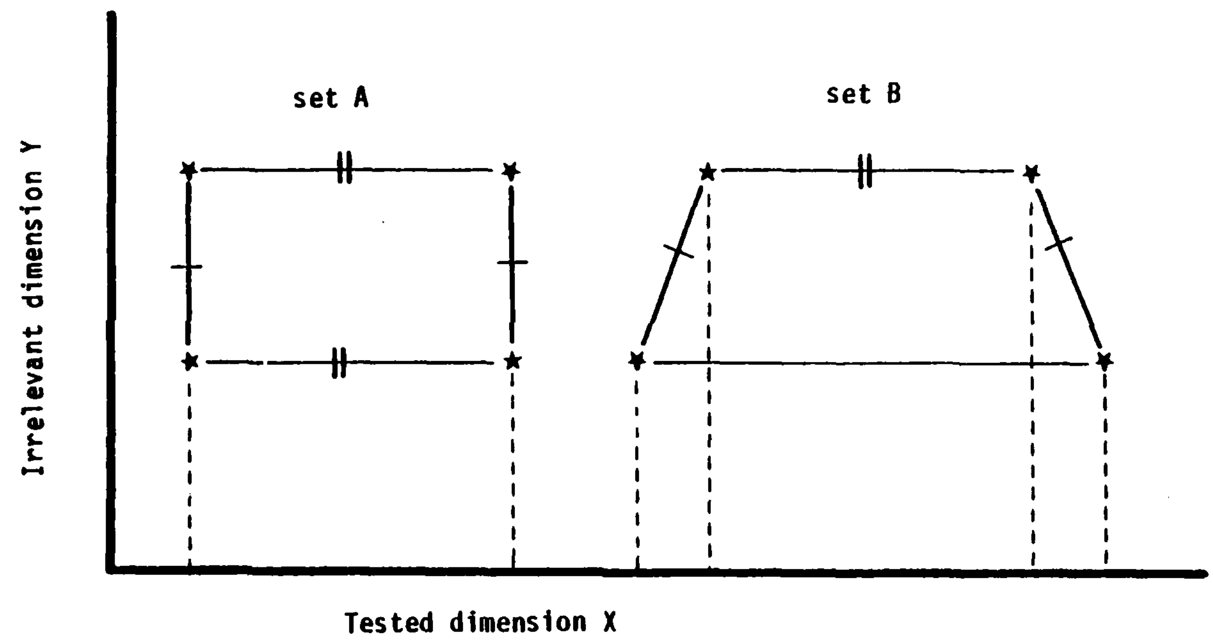

Figure 17. Schematic diagram of stimulus sets in test of separability of dimension. Dotted lines denote projections on dimension X.

rather than divided attention, and that it need involve selective attention to only one dimension.

5.3 Summary

Two related lines of reasoning run through this dissertation. The first line attempts to show that two crucial operations defining integrality and separability (interference and condensation time in speeded sorting)- and two phenomena that fall in between the concepts of integrality and separability (degrees of integrality and asymmetric integrality) can result from the degrees of compatibility between physical dimensions and psychological (i.e., separable) dimensions.

Experiment I showed that a psychophysically compatible dimension did not produce interference, whereas psychophysically incompatible dimensions did, as predicted by the psychophysical compatibility theory. In this experiment, compatibility was defined by the compellingness of dimensions. Experiment II showed that degrees of compatibility (as defined by the orientations of sets of stimuli in a multidimensional scaling representation of overall similarity judgments) could explain the occurrence of interference, the inverse relationship between interference and condensation time, and degrees of integrality (as indicated by gradations of the pattern of interference and condensation time). Experiment III attempted to show that in accordance with the compatibility theory, the compatibility of single dimensions can generally be evaluated independently of the compatibility of concomitantly varied dimensions. This independence implies that if one manipulated dimension is psychophysically compatible while another is not, asymmetric integrality will

result. In this experiment, the compatibility of a dimension was evaluated in the context of two irrelevant dimensions, as well as with different values along the same irrelevant dimension. Compatibility was defined phenomenologically as well as by the amount of interference. Results showed that the compatibility of a dimension was not consistently affected by variation along other dimensions.

A second line of reasoning explores the appropriateness of rectangularity as a systematic definition of psychophysically compatible dimensions. A definition of such dimensions independent of speeded classification performance is essential to the viability of the compatibility theory. Experiment II showed that rectangularity was not a sufficient definition of psychological dimensions, since the orientation of the axes in a similarity space was a determinant of sorting performance. Experiment III showed that the degree of rectangularity, caused by variation along the irrelevant dimension, did not consistently affect the amount of interference in sorting along the relevant dimension.

Experiment IV was a test of the necessity of rectangularity. It was argued that overall similarity judgments, on which rectangularity is based, require the subject to either divide attention or to combine information obtained by sequentially attending to two or more dimensions, but that the definition of a psychological dimension need require no more than the ability to independently attend to only one dimension. Rectangularity should therefore be unnecessary as a definition of psychological dimensions. Results of Experiment IV tentatively showed that psychological dimensions need not produce

rectangular configurations. It was suggested that a definition of psychological dimensions should be based on selective attention, and that it should require selective attention to only one dimension.

The findings of Experiments I to III at least imply that Garner's (1974) definition of integrality is inadequate. In place of his definition, two new operations were proposed: the effect of dimensional within-class variability with appropriate controls, and the effect of the orientation of a fixed configuration. The findings furthermore imply that a single type of internal representation (the "separable" type) may account for integrality and separability.

APPENDICES

APPENDIX A

INSTRUCTIONS FOR DISSIMILARITY JUDGMENTS

In this experiment I'll show you pairs of triangles, like this one, and ask you to judge how dissimilar the triangles are. You are to rate the degree of dissimilarity of a pair of triangles on a scale of one to ten. If the triangles are almost identical, that is, the dissimilarity between them is very small, give the pair a small number. If the triangles are very dissimilar, give them a high number. For intermediate levels of dissimilarity, give them an intermediate number.

You are to indicate your rating of a pair by pressing the corresponding one of these ten buttons. For a score of one press the button at the far left; for a score of ten, press the button at the far right. There are labels on the two extremes.

I'm interested in your subjective impression of the degree of dissimilarity between triangles. Thus, there are no correct or incorrect answers. I'm not at all concerned with your ability to do geometry; just look at the pair of triangles for a short time, and press a button corresponding to your general impression of how dissimilar the triangles are. The number that you press should <u>reflect</u> how different they look to you. It shouldn't be just according to some arbitrary rule that you've worked out. This is not a speeded task, but don't spend too much time deliberating.

First, you'll see all of the triangles in the set, one at a time, in a random order, to get an idea of how varied they are. This

is one of the triangles. To see the remaining triangles, push any button, and the next triangle will appear. After all of the individual triangles in the set have been displayed -- there are sixteen of them -- they will start appearing in pairs. When you press a button indicating your dissimilarity rating of the pair, that pair will disappear and the next one will be displayed.

There will be short breaks between blocks of 120 pairs.

Do you have any questions?

APPENDIX B

INSTRUCTIONS FOR SORTING

Your job today is to sort triangles into two categories. You indicate your response by depressing one of two keys, with either your right or left index finger. Here are the response keys. You are to sort the triangles according to instructions which will be given on the screen.

Frist, let me show you the set of triangles to be presented today. You may use the sheet as a reference to form a firmer idea of the task. For instance, to help you remember, you may want to jot down the numbers of the triangles in each category during the instructions. Do not look at this sheet, however, when you are doing the actual trials. You may look at it during the practice trials.

At the beginning of each sorting task, instructions will appear on the screen in a series of still frames. To proceed to the next frame, simply press a response key. During the instructions, you may study each frame for as long as you need. You will be shown the triangles to be classified one by one, and you will be informed which response class, LEFT or RIGHT, each triangle belongs to. On some trials there will be four triangles, two in each class. On other trials, there'll be only two triangles, one in each class. In each block, there'll be 12 practice trials followed by 40 actual trials. The word READY will appear before the first practice and the first actual trial. When you are ready to begin, depress a key.

On each trial, respond as accurately as possible, and within that limitation, as quickly as possible. Try not to make more than one, or at most two errors in a block. You should try to keep your error rate below 3%, which means fewer than 1.2 errors on the average within a block of 40 actual trials. At the same time, be as fast as possible. Never wait for more than two seconds to make a response. If you've waited that long and are still not sure, make your best guess and respond anyway. It's best if you can keep your reaction time always below one second.

It's important that we get good data. Thus, if on a certain day you find that you have trouble concentrating on the task -- you have a hang-over, you have an exam to worry about, whatever -- let me know. We'll reschedule the session. Bad data is a waste of your time and mine.

Do you have any questions?

APPENDIX C

ANALYSIS OF VARIANCE FOR EXPERIMENT I: PART ONE - ACROSS TASKS

Source	D.F.	Mean Square	F
Subject (S)	1	179101	
Task type (T)	1	304860	69.5[1]
Dimensional distance (D)	1	3547	.33
Euclidean distance (E)	1	7022	1.60
T x D	1	131192	29.9
T x E	1	13257	.83
D x E	1	14746	3.36
T x D x E	1	24175	.87
S x T	1	540	
S x D	1	10636	
S x E	1	315	
S x T x D	1	4052	
S x T x E	1	15929	
S x D x E	1	15	
J x T x D x E	1	27794	
Residual	1904	4584	

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[1]When the mean square for the interaction between S and a given factor is less than the mean square (E) for Tr pooled across the orthogonal and unidimensional tasks, E is used instead as an estimate of error for calculating F's.

APPENDIX D

ANALYSIS OF VARIANCE FOR EXPERIMENT I: PART ONE - INDIVIDUAL TASKS - ORTHOGONAL SORTING

Source	D.F.	Mean Square	F
Subject (S)	1	59985	
Dimensional distance (D)	1	66708	6.39
Euclidean distance (E)	1	14841	3.37
Run (R)	1	45866	10.51
S x D	1	10432	
S x E	1	4410	
D x E	1	28756	2.63
S x R	1	774	
D x R	1	1531	.14
E x R	1	36090	8.25
Stimulus (St) within D x E	12	7372	.96
S x D x E	1	10923	
S x D x R	1	11088	
S x E x R	1	4	
D x E x R	1	20227	4.62
S x St within D x E	12	7643	
St x R within D x E	12	2502	.44
S x D x E x R	1	1177	
Trial (Tr) within S x D x E x St	288	4374	
S x St x R within D x E	12	5717	
R x Tr within S x D x D x St	288	4221	

[1] When the mean square for the interaction between S and a given factor is less than the mean square (E) for Tr for that task, E is used instead as an estimate of error for calculating F's.

APPENDIX D (CON'T)

ANALYSIS OF VARIANCE FOR EXPERIMENT I: PART ONE - INDIVIDUAL TASKS - UNIDIMENSIONAL SORTING

Source	D.F.	Mean Square	F
Subject (S)	1	125652	
Interstimulus distance (I)	1	19315	1.80
Run (R)	1	3006	.33
Stimulus set (G) within I	4	16395	1.16
S x I	1	10730	
S x R	1	8989	
I x R	1	7019	.68
Stimulus (St) within I x G	6	5197	.85
S x G within I	4	14118	
G x R within I	4	6380	.94
S x I x R	1	10365	
S x St within I x G	6	6088	
St x R within I x G	6	3762	.86
S x G x R within I	4	6752	
Trial (Tr) within S x I x G x St	456	4393	
S x St x R within I x G	6	2385	
R x Tr within S x I x G x St	456	3873	

[1]When the mean square for the interaction between S and a given factor is less than the mean square (E) for Tr, E is used instead as an estimate of error for calculating F's.

APPENDIX E

ANALYSIS OF VARIANCE FOR EXPERIMENT I: PART TWO - ACROSS TASKS

Source	D.F.	Mean Square	F
Subject (S)	1	76184	
Task type (T)	1	1497998	10.4
Dimensional distance (D)	1	331303	20.8
Euclidean distance (E)	1	57365	1.84
T x D	1	114537	5.61
T x E	1	53446	1.56
D x E	1	26260	4.46[1]
T x D x E	1	1969	.33
S x T	1	144354	
S x D	1	15925	
S x E	1	31133	
S x T x D	1	20405	
S x T x E	1	34284	
S x D x E	1	4598	
S x T x D x E	1	3507	
Residual	1904	6930	

[1]When the mean square for the interaction between S and a given factor is less than the mean square (E) for Tr, E is used instead as an estimate of error for calculating F's.

APPENDIX F

ANALYSIS OF VARIANCE FOR EXPERIMENT I: PART TWO - INDIVIDUAL TASKS - ORTHOGONAL SORTING

Source	D.F.	Mean Square	F
Subject (S)	1	4050	
Dimensional distance (D)	1	21091	.77
Euclidean distance (E)	1	83083	1.69
Run (R)	1	359386	46.8[1]
S x D	1	27144	
S x E	1	49035	
D x E	1	15980	2.08
S x R	1	1092	
D x R	1	86862	8.68
E x R	1	187	.006
Stimulus (St) within D x E	12	17763	2.32
S x D x E	1	6051	
S x D x R	1	10001	
S x E x R	1	32319	
D x E x R	1	9180	.18
S x St within D x E	12	4457	
St x R within D x E	12	21959	2.86
S x D x E x R	1	52020	
Trial (Tr) within S x D x E x St	288	7673	
S x St x R within D x E	12	6759	
R x Tr within S x D x E x St	288	9700	

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[1] Ibid.

APPENDIX F (CON'T)

ANALYSIS OF VARIANCE FOR EXPERIMENT I: PART TWO - INDIVIDUAL TASKS - UNIDIMENSIONAL SORTING

Source	D.F.	Mean Square	F
Subject (S)	1	123552	
Interstimulus distance (I)	1	606685	106.
Run (R)	1	410624	5.77
Stimulus set (G) within I	4	70791	4.07
S x I	1	5692	
S x R	1	71155	
I x R	1	21418	4.36[1]
Stimulus (St) within I x G	6	8206	1.67
S x G within I	4	17367	
G x R within I	4	6048	.51
S x I x R	1	484	
S x St within I x G	6	3081	
St x R within I x G	6	11080	2.26
S x G x R within I	4	11767	
Trial (Tr) within S x I x G s St	456	4910	
S x St x R within I x G	6	3181	
R x Tr within S x I x G x St	456	5192	

[1]When the mean square for the interaction between S and a given factor is less than the mean square (E) for Tr, E is used instead as an estimate of error for calculating F's.

APPENDIX G

STIMULUS VALUES FOR INDIVIDUAL SUBJECTS IN EXP II

D.B.: original set (listed by column) / rotated set (listed by column)

α°	R in 1/16 inch	α°	R
72	16	62	16
72	24	66	20
73	30	71	24
74	34	73	30
55	18	52	22
57	21	59	26
61	26	61	30
61	29	64	37

R.H.: original set / rotated set

α°	HxR in $(1/16)^2$ inch	α°	HxR
8	360	13	640
22	520	22	470
38	530	37	326
55	538	58	265
11	1150	19	2100
22	1170	29	1200
38	1180	42	870
53	1364	60	905

APPENDIX H

ANALYSIS OF VARIANCE TABLES IN EXPERIMENT II

Subject D.D.: across tasks

Source	D.F.	Mean Square	F
Orientation (O)	1	75613	3.48
Task type (T)	4	5959853	274.3
O x T	4	189815	8.7
Residual	3030	24709	

Subject D.B.: unidimensional (H)

Source	D.F.	Mean Square	F
O	1	17067	2.22
Run (R)	1	112970	14.7
Stimulus set (G) within O	6	45153	5.88
O x R	1	22645	2.95
Stimulus (St) within G	8	7013	0.91
G x R within O	6	16476	2.15
Trial (Tr) within St	304	7676	
St x R within G	8	4487	0.58
R x Tr within St	304	6460	0.84

APPENDIX H (CON'T)

Subject D.B.: unidimensional (V)

Source	D.F.	Mean Square	F
0	1	6573	0.97
R	1	69905	10.28
G within 0	4	69639	10.24
0 x R	1	5217	0.77
St within G	18	19385	2.85
G x R within 0	4	7323	1.08
Tr within St	456	6797	
St x R within G	18	11183	1.65
R x Tr within St	456	6896	1.01

Subject D.B.: orthogonal (H)

Source	D.F.	Mean Square	F
0	1	197437	22.6
R	1	265033	30.3
G within 0	4	7478	0.85
0 x R	1	86483	9.88
St within G	18	8375	0.96
G x R within 0	4	39101	4.47
Tr within St	216	8750	
St x R within G	18	6449	0.74
R x Tr	216	8750	1.00

APPENDIX H (CON'T)

Subject D.B.: orthogonal (V)

Source	D.F.	Mean Square	F
O	1	277296	23.4
R	1	30544	3.62
G within O	4	658807	55.6
O x R	1	10782	0.91
St within G	18	59801	5.05
G x R within O	4	12045	1.02
Tr within St	216	11839	
St x R within G	18	11707	0.99
R x Tr within St	216	15133	1.28

Subject D.B.: diagonal

Source	D.F.	Mean Square	F
O	1	330067	3.44
R	1	55	0.5^{-3}
G within O	4	626183	6.53
O x R	1	136788	1.43
St within G	18	130602	1.25
G x R within O	4	238901	2.49
Tr within St	216	95863	
St x R within G	18	74002	0.77
R x Tr within St	216	94386	0.98

APPENDIX H (CON'T)

Subject R.H.: across tasks

Source	D.F.	Mean Square	F
O	1	41289	1.88
T	4	8046791	367.0
O x T	4	537760	24.5
Residual	3030	25953	

Subject R.H.: unidimensional (H)

Source	D.F.	Mean Square	F
O	1	84	0.01
R	1	19228	3.05
G within O	6	24950	3.96
O x R	1	6039	0.96
St within G	8	9846	1.56
G x R within O	6	13797	2.19
Tr within St	304	6299	
St x R within G	8	11460	1.82
R x Tr within St	304	5890	0.94

APPENDIX H (CON'T)

Subject R.H.: unidimensional (V)

Source	D.F.	Mean Square	F
O	1	12	0.6^{-3}
R	1	2184	0.12
G within O	4	478887	25.4
O x R	1	377071	20.0
St within G	18	38204	2.03
G x R within O	4	45054	2.39
Tr within St	456	18818	
St x R within G	18	42072	2.24
R x Tr within St	456	20258	1.08

Subject R.H.: orthogonal (H)

Source	D.F.	Mean Square	F
O	1	367	0.03
R	1	167776	11.9
G within O	4	95617	6.76
O x R	1	24739	1.75
St within G	18	19471	1.38
G x R within O	4	29264	2.07
Tr within St	216	14138	
St x R within G	18	12620	0.89
R x Tr within St	216	13564	0.96

APPENDIX H (CON'T)

Subject R.H.: orthogonal (V)

Source	D.F.	Mean Square	F
O	1	651287	27.8
R	1	179065	7.65
G within O	4	221101	9.45
O x R	1	194206	8.29
St within G	18	36888	1.58
G x R within O	4	200597	8.57
Tr within St	216	23409	
St x R within G	18	18176	0.78
R x Tr within St	216	26233	1.12

Subject R.H.: diagonal

Source	D.F.	Mean Square	F
O	1	1527650	26.9
R	1	78873	1.39
G within O	4	543456	9.56
O x R	1	3735	0.07
St within G	18	70378	1.24
G x R within O	4	72074	1.27
Tr within St	216	56822	
St x R within G	18	142944	2.52
R x Tr within St	216	60502	1.06

APPENDIX I

ANALYSIS OF VARIANCE FOR EXPERIMENT III: PART ONE

ACROSS TASKS

Source	D.F.	Mean Square	F
Subject (S)	1	155321	
Task (T)	1	747487	41.6
Compatibility (C)	1	23635	4.81[1]
Interaction (I)	1	8279	0.43
T X C	1	16808	0.67
T X I	1	6400	1.30
C X I	1	42118	8.58
T X C X I	1	35278	7.19
S X T	1	17984	
S X C	1	1481	
S X I	1	19352	
S X T X C	1	25168	
S X T X I	1	2925	
S X C X I	1	4055	
Residual	2065	4740	

[1] See footnote on Appendix C, page 124.

APPENDIX I (CONTINUED)

ANALYSIS OF VARIANCE FOR EXPERIMENT III: PART ONE

ORTHOGONAL SORTING

Source	D.F.	Mean Square	F
Subject (S)	1	24626	
Compatibility (C)	1	211	0.04
Interaction (I)	1	10660	1.86
Run (R)	1	58102	10.2
S X C	1	14156	
S X I	1	13597	
C X I	1	56325	8.58
S X R	1	10304	
C X R	1	79	0.01
I X R	1	36210	6.33
Stimulus (St) within C X I	12	13241	2.31
S X C X I	1	465	
S X C X R	1	29214	
S X I X R	1	980	
C X I X R	1	47025	8.22
S X St within C X I	12	3077	
St X R within C X I	12	7211	0.80
S X C X I X R	1	5130	
Trial (Tr) within S X C X I X St	288	5720	
S X St X R within C X I	12	8995	
R X Tr within S X C X I X St	288	5566	

APPENDIX J

ANALYSIS OF VARIANCE FOR EXPERIMENT III: PART TWO

ACROSS TASKS

Source	D.F.	Mean Square	F
Subject (S)	1	38424	
Task (T)	1	2970986	245.0
Dimensional distance (D)	1	135458	1.70
Interaction (I)	1	139961	2.13
T X D	1	74333	1.57
T X I	1	72115	10.0
D X I	1	136600	1.18
T X D X I	1	458	0.07
S X T	1	12109	
S X D	1	79834	
S X I	1	65761	
S X T X D	1	47285	
S X T X I	1	7180	
S X D X I	1	116237	
S X T X C X I	1	90646	
Residual	1904	8127	

APPENDIX J (CONTINUED)

ANALYSIS OF VARIANCE FOR EXPERIMENT III: PART TWO

ORTHOGONAL SORTING

Source	D.F.	Mean Square	F
Subject (S)	1	2772	
Dimensional distance (D)	1	3413	0.04
Interaction (I)	1	154878	14.0
Run (R)	1	482241	9.11
S X D	1	93750	
S X I	1	11055	
D X I	1	45461	0.29
S X R	1	52925	
D X R	1	172462	7.87
I X R	1	6604	0.71
Stimulus (St) within D X I	12	23676	2.55
S X D X I	1	154567	
S X D X R	1	21925	
S X I X R	1	297	
D X I X R	1	612	0.8^{-2}
S X St within D X I	12	4287	
St X R within D X I	12	25425	2.73
S X D X I X R	1	76256	
Trial (Tr) within S X D X I X St	288	9298	
S X St X R within D X I	12	4930	
R X Tr within S X D X I X St	288	9945	

APPENDIX K

ANALYSIS OF VARIANCE FOR INDIVIDUAL SUBJECTS IN EXPERIMENTS IV

Subject D.B.

Across tasks:

Source	D.F.	Mean Square	F
Attribute (A)	1	1392235	110.4
Discriminability (D)	5	2605749	206.6
Task type (T)	3	593448	47.1
A x D	5	1209505	95.9
A x T	3	45610	3.62
D x T	15	76249	6.05
A x D x T	15	38497	3.05
Residual	4752	13072	

Unidimensional sorting:

Source	D.F.	Mean Square	F
A	1	651213	72.4
D within A	10	469397	4.22
Stimulus set (S) within D	36	21288	2.37
Stimulus (St) within S	48	14795	1.64
Trial (Tr) within St	1824	8999	

Orthogonal sorting: low irrelevant discriminability:

Source	D.F.	Mean Square	F
A	1	598250	38.5
D	10	734468	47.3
S	24	38514	2.48
St	108	15164	0.98
Tr	1296	15533	

APPENDIX K (CONT)

ANALYSIS OF VARIANCE FOR INDIVIDUAL SUBJECTS IN EXPERIMENTS IV

Subject D.B.: orthogonal sorting: medium irrelevant discriminability:

Source	D.F.	Mean Square	F
A	1	819352	50.4
D	10	784852	48.3
S	12	27645	1.70
St	72	17839	1.10
Tr	864	16246	

Orthogonal sorting: high irrelevant discriminability:

Source	D.F.	Mean Square	F
A	1	45347	3.83
D	10	316937	26.8
St	36	21296	1.80
Tr	432	11839	

Subject R.H.

Across tasks:

Source	D.F.	Mean Square	F
A	1	197	0.03
D	5	1036161	140.0
T	3	686205	92.6
A x D	5	183643	24.8
A x T	3	14541	1.96
D x T	15	33729	4.55
A x D x T	15	23125	3.12
Residual	4752	7831	

APPENDIX K (CONT)

ANALYSIS OF VARIANCE FOR INDIVIDUAL SUBJECTS IN EXPERIMENTS IV

Subject R.H.

Unidimensional sorting:

Source	D.F.	Mean Square	F
A	1	332	0.05
D	10	223213	36.1
S	36	16254	2.59
St	48	9034	1.44
Tr	1824	6274	

Orthogonal sorting:

Low irrelevant discriminability:

Source	D.F.	Mean Square	F
A	1	20003	3.16
D	10	246654	39.0
S	24	29855	4.72
St	108	9404	1.49
Tr	1296	6322	

Orthogonal sorting: medium irrelevant discriminability:

Source	D.F.	Mean Square	F
A	1	11949	1.36
D	10	159027	18.1
S	12	18095	2.06
St	72	10352	1.18
Tr	864	8797	

APPENDIX K (CONT)

ANALYSIS OF VARIANCE FOR INDIVIDUAL SUBJECTS IN EXPERIMENTS IV

Subject R.H.

Orthogonal sorting: high irrelevant discriminability:

Source	D.F.	Mean Square	F
A	1	16791	1.32
D	10	154881	12.2
S	36	21602	1.70
Tr	432	12701	

Subject S.S.

Across tasks:

Source	D.F.	Mean Square	F
A	1	1116	0.11
D	5	1260389	127.2
T	3	762362	77.0
A x D	5	182810	18.5
D x T	15	98102	9.90
Residuals	4726[1]	9905	

Orthogonal sorting: Unidimensional:

Source	D.F.	Mean Square	F
A	1	1894	0.24
D	5	111786	14.3
S	18	22773	2.92
St	24	21640	2.77
Tr	1847	7799	

[1] RTs over 3 standard deviations from the mean were discarded from the data of this subject.

APPENDIX K (CONT)

ANALYSIS OF VARIANCE FOR INDIVIDUAL SUBJECTS IN EXPERIMENTS IV

Subject S.S.

orthogonal sorting: low irrelevant discriminability:

Source	D.F.	Mean Square	F
A	1	1507	0.15
D	5	478198	47.9
S	12	13313	1.34
St	54	14511	1.46
Tr	1361	9969	

Orthogonal sorting: medium irrelevant discriminability:

Source	D.F.	Mean Square	F
A	1	7	.0006
D	5	542291	46.8
S	6	4613	3.8
St	36	18971	1.63
Tr	903	11587	

Orthogonal sorting: high irrelevant discriminability:

Source	D.F.	Mean Square	F
A	1	1509	0.11
D	10	179197	12.9
St	36	9423	0.9
Tr	426	13850	

REFERENCES

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Attneave, F. Dimensions of similarity. American Journal of Psychology, 1950, 63, 516-556.

Beals, R., Krantz, D. H., & Tversky, A. Foundations of multidimensional scaling. Psychological Review, 1968, 75, 127-142.

Boring, E. G. A History of Experimental Psychology, 2nd edition, Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1957.

Brown, D. R., & Andrews, M. H. Visual form discrimination: Multidimensional analysis. Perception and Psychophysics, 1968, 3, 401-406.

Cheng, P. & Pachella, R. G. Multidimensional scaling criteria for defining the integrality of psychological dimensions. Paper presented at the annual meeting of the Midwestern Psychological Association, Chicago, May, 1979.

Chipman, S. F. & Carey, S. Anatomy of a stimulus domain: The relation between multidimensional and unidimensional scaling of noise bands. Perception and Psychophysics, 1975, 17, 417-424.

Chipman, S. F. & Noma, E. The compatibility of psychophysical judgements: The shape of rectangles. Unpublished manuscript, University of Michigan, 1979.

Day, R. S., & Wood, C. C. Interactions between linguistic and nonlinguistic processing. Journal of the Acoustical Society of America, 1972, 51, 79.

Garner, W. R. The stimulus in information processing. American Psychologist, 1970, 25, 350-358.

Garner, W. R. The Processing of Information and Structure. Potomac, Md.: Lawrence Erlbaum Associates, 1974.

Garner, W. R. Selective attention to attribute and to stimuli. Journal of Experimental Psychology: General, 1978, 107, 287-308.

Garner, W. R. & Felfoldy, G. L. Integrality of stimulus dimensions in various types of information processing. Cognitive Psychology, 1970, 1, 225-241.

Gibson, J. J. The concept of the stimulus in psychology. American Psychologist, 1960, 15, 694-703.

Gibson, J. J. The Senses Considered as Perceptual Systems. Boston: Houghton Mifflin, 1966.

Gottwald, R. L. & Garner, W. R. Filtering and condensation tasks with integral and separable dimensions. Perception and Psychophysics, 1975, 18, 26-28.

Gregory, R. L. Eye and Brain: The Psychology of Seeing. New York: McGraw-Hill Book Company, 1966.

Handel, S., & Imai, S. The free classification of analyzable and unanalyzable stimuli. Perception and Psychophysics, 1972, 12, 108-116.

Hyman, R., & Well, A. Judgements of similarity and spatial models. Perception and Psychophysics, 1967, 2, 233-248.

Kemler, D. G. & Smith, L. B. Accessing similarity and dimensional relations: Effects of integrality and separability on the discovery of complex concepts. Journal of Experimental Psychology: General, 1979, 108, 133-150.

Kohler, W. Gestalt Psychology, 2nd ed., New York: Liveright, 1947.

Krantz, D. H. Measurement structures and psychological laws. Science, 1972, 175, 1427-1435.

Krantz, D. H. & Tversky, A. Similarity of rectangles: An analysis of subjective dimensions. Journal of Mathematical Psychology, 1975, 12, 4-34.

Kuhn, T. S. The Structure of Scientific Revolutions, 2nd ed., Chicago: The University of Chicago Press, 1970.

Lockhead, G. R. Effects of dimensional redundancy on visual discrimination. Journal of Experimental Psychology, 1966, 72 95-104.

Lockhead, G. R., & King, M. C. Classifying integral stimuli. Journal of Experimental Psychology: Human Perception and Performance, 1977, 3, 436-443.

Noma, E., & Johnson, J. Confirmatory multidimensional scaling. Human Performance Center Technical Report No. 60. University of Michigan, August, 1977.

Pachella, R. G., Somers, P., & Hardzinski, M. A psychophysical approach to dimensional integrality. To appear in D. Getty and J. Howard (Eds.), Auditory and Visual Pattern

Recognition (title tentative), Lawrence Erlbaum Associates, New York, 1980.

Platt, J. R. Strong Inference. Science, 1964, 146, 347-353.

Pomerantz, J. R. & Garner, W. R. Stimulus configuration in selective attention tasks. Perception and Psychophysics, 1973, 14, 565-569.

Pomerantz, J. R. & Sager, L. C. Asymmetric integrality with dimensions of visual pattern. Perception and Psychophysics, 1975, 18, 460-466.

Posner, M. I. Information reduction in the analysis of sequential tasks. Psychological Review, 1964, 71, 491-504.

Robinson, J. O. The Psychology of Visual Illusion. London: Hutchinson & Co. Ltd, 1972.

Shepard, R. N. Attention and the metric structure of the stimulus space. Journal of Mathematical Psychology, 1964, 1, 54-87.

Smith, L. B. & Kemler, D. G. Levels of experienced dimensionality in children and adults. Cognitive Psychology, 1978, 10, 502-532.

Somers, P., & Pachella, R. G. Interference among sources of information in complex integrated displays. Human Performance Center Technical Report No. 58. University of Michigan, February, 1977.

Somers, P. Perceptual interaction between stimulus dimensions as the basis of dimensional integrality. Human Performance Center Technical Report No. 61. University of Michigan, October, 1978.

Stevens, S. S. The volume and intensity of tones. American Journal of Psychology, 1934, 46, 397-408.

Stevens, S. S. Mathematics, measurement, and psychophysics. In S. S. Stevens (Ed.), Handbook of Experimental Psychology. New York: Wiley, 1951, 1-49.

Stevens, S. S., & Davis, H. Hearing: Its Psychology and Physiology. New York: Wiley, 1938.

Torgerson, W. S. Theory and Methods of Scaling. New York: Wiley, 1958.

Townsend, J. T. Issues and models concerning the processing of a finite number of inputs. In B. Kantowitz (Ed.), Human Information Processing: Tutorials in Performance and Cognition. New York: Lawrence Erlbaum Associates, 1974.

Tversky, A. Features of similarity. Psychological Review, 1977, 84, 327-352.

Tversky, A. & Krantz, D. H. The dimensional representation and the metric structure of similarity data. Journal of Mathematical Psychology, 1970, 7, 572-596.

Weintraub, D. J. Rectangle discriminability: Perceptual relativity and the law of Pragnanz. Journal of Experimental Psychology, 1971, 88, 1-11.

Wood, C. C. Parallel processing of auditory and phonetic information in speech discrimination. Perception and Psychophysics, 1974, 15, 501-508.

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